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THE NATURAL RESOURCES OF PITTSBURG.

[PAPER read by Edgar P. Allen before the Engineers' Society of Western Pennsylvania, in advance of its being published in the souvenir hand-book of the visit of the Iron and Steel Institute of Great Britain and the Verein Deutscher Eisenhüttenleute, October 9 to 12, 1890.]

PITTSBURG AND VICINITY.

Situation of Pittsburg and Allegheny City.—The City of Pittsburg, is situated in western Pennsylvania, some thirty-five miles from the West Virginian boundary. It covers the tongue of land between the Allegheny and Monongahela rivers at their confluence on the Ohio, as well as the narrow strip of the southern shore of the Monongahela whence it has spread to some extent over the hills behind. The southern shore of the Monongahela is known as the "South Side" of Pittsburg. The "Sister City" of Pittsburg, Allegheny City, covers the shore and highlands north of the Allegheny river. In all questions of business and social relations, the two cities are one, and they will be so considered in this sketch, although they have separate city governments.

The main commercial business of Pittsburg and Allegheny City is done in the point between the rivers; the manufacturing establishments are spread along the shores of the two rivers; and the people reside for the most part, on the highlands of Allegheny to the northward, and of Pittsburg to the eastward. The latter, known as "East End," is a fine stretch of high rolling country, some fifteen square miles in extent, occupied by numerous suburban places, the homes, for the most part, of the manufacturers of Pittsburg.

Historical Sketch.—Pittsburg is quite an old city, as American cities go, and its purpose in history has been manifest from the first; it has always been a city of manufactures. The nucleus of the city of Pittsburg was the French Fort Duquesne, situated at the point between the rivers. The fort was abandoned by the French in November, 1758, before the advance of General Forbes, and the first recorded use of the name Pittsburg occurs in a letter from General Forbes, dated the day after his taking possession, "from Fort Duquesne, now Pittsburg, the 26th of November, 1758." The ruins of Fort Duquesne were held until the first, and afterwards a second, Fort Pitt was built. The only existing remains of the early fortifications are a block house on Fort street near Penn avenue, built by Colonel Bouquet, and formerly bearing the date 1764.

In 1790 Pittsburg contained some four or five hundred inhabitants; in 1890, after one hundred years, its population is, together with that of Allegheny City, upwards of 400,000.

The people who settled along the banks of these rivers, and made the beginnings of this "three-legged place" of Carlyle, soon discovered that the country contained something far better worth the expense of their energies than the Indian trade could ever be. By virtue of its geographical position, and its wealth of coal and gas, Pittsburg was intended for a manufacturing centre, and a manufacturing centre it has become.

Natural Resources.

Coal Fields.—The bituminous coal-field of western Pennsylvania, by which Pittsburg is surrounded, is estimated to contain 14,000 square miles. The seams in this field crop out on the flanks of the hills and banks of the rivers, and the veins reach in places a thickness of ten feet and more, so that the cost of bringing the coal to market has been reduced to a very small figure, as is evident from the fact that in the suburbs of the city, first-class coal can be had for five cents a bushel, and the run of mines for as little as three and three-quarter cents. The counties immediately surrounding Pittsburg, namely, Allegheny, Washington, Fayette, and Westmoreland, furnish annually over 13,000,000 tons of

coal, about 20 per cent. of the whole product of the United States.

The coal of Allegheny is an excellent steam coal, and is also used extensively for the manufacture of illuminating gas; the coal of Westmoreland county is superior to the former for both purposes. To the southeast the coal is specially adapted to the manufacture of coke. The principal source is the Pittsburg seam; another important source is the upper Freeport bed. The coal consumed in Pittsburg and vicinity is almost entirely confined to blast-furnace use, and in the form of coke. There are in Allegheny county 81 coal mines, having an approximate aggregate output of 5,750,000 tons per year. The bulk of this, about 4,000,000 tons, is shipped down the river in barges, some of it as far as New Orleans, into which port British vessels often put in to coal.

Natural Gas.—The earliest economic use of natural gas in this country was probably as an illuminant in the village of Fredonia, Chautauqua county, New York. In the year 1821, Humboldt is quoted as declaring the natural gas of Fredonia to be the "eighth wonder of the world." No one at that time suspected the vast volume of gas confined beneath the surface of western Pennsylvania, and New York, nor the immense and important uses to which it would be put after some fifty years. The first use of gas in iron works occurred in the works of Messrs. Rodgers & Burchfield, in Leechburg, on the north bank of the Kiskiminetas river, in Armstrong county, in 1873. The gas used by this company came from the so-called Leechburg gas well, which was bored for oil in 1870 and 1871, and in which the gas vein was struck at a depth of 1200 feet. In 1875 a well in Butler county, known as the "Harvey Well," was purchased by the Natural Gas Company, limited, the first natural gas company. Its gas was piped 17 miles through a 6-inch iron pipe to the mill of Messrs. Spang, Chalfant & Co., at Etna, Pittsburg; the gas traversed the 17 miles in 20 minutes, the observed pressure at the wells being 119 pounds. In 1883, Capt. J. B. Ford, of the Pittsburg Plate Glass Company, applied natural gas as a fuel to the manufacture of glass. It is noteworthy that the discovery of natural gas has

lent considerable impetus to the manufacture of glass, particularly of plate glass. Within the last seven years the example of the pioneers in the use of natural gas has been quickly followed by other companies, until now almost none of the important manufacturers of Pittsburg, of metal or of glass, use any other fuel.

The chief sub-districts of the Pittsburg natural gas field are the Murrysville, being the most important, lying to the eastward, the Grapesville, Canonsburg, Hickory, Sheffield, Baden, Tarentum and Pine Run. All of these are distributed within a semi-circle, having a radius of about 20 miles, with Pittsburg as the centre. From almost all of the wells within this 20-mile circle gas is piped to Pittsburg and Allegheny. The conduits used are iron pipes, wrought iron for the smaller and cast-iron for the larger diameters. The majority of the mains are about 16-inches in diameter; recently, however, the Philadelphia Company, in order to lessen the friction in the pipe and to increase the supply of gas in Pittsburg, have made arrangements to lay a 36-inch riveted steel pipe from the Murrysville district toward Pittsburg.

In some instances gas has been conveyed through iron pipes more than 60 miles from the wells, as, for instance, from the Northwestern Pennsylvania field to the city of Buffalo, New York. The number of miles of pipe leading into Pittsburg and vicinity, and distributing gas therein may be estimated at 1200, of which 750 are owned and controlled by the Philadelphia Company. The capital invested in natural gas in and about Pittsburg may be estimated at $15,000,000.

While persistent experiments have made it possible to measure, with some degree of accuracy, the yield of gas of each well, day by day, such measurements are not taken sufficiently often at individual wells, or at a sufficient number of wells to make it safe to base on them a calculation of the amount of gas annually consumed. It is necessary to base such calculations on an estimation of the amount of coal displaced by natural gas. Experiments have shown that 27,000 feet of gas are equal in efficiency to one gross ton of coal, according to which, as the amount of coal displaced in Allegheny county and the remainder of the Pittsburg district is 5,000,000 tons (a figure based on the probable

difference between the quantity of coal consumed before natural gas was generally employed, and the quantity of coal now consumed in the same district), then the average annual consumption of gas may be estimated at something over 100,000,000,000 feet ; this is equivalent to a value of $6,500,000.

Petroleum.—The Pennsylvania and New York oil-fields, the latter of which is an extension of the former, lie almost wholly within the basin of the Allegheny river, to the northeast of Pittsburg, and extend to the southwest of this city with some degree of regularity nearly as far as the West Virginia line. Owing to the fluctuating output of each individual locality, accurate data as to the same can be obtained only with the greatest difficulty, and complete figures can only be given for the total production of the two states, which is as follows:

	Bbls.
Total production of petroleum for 1889, . .	22,376,690
Average production per day for 1889, . . .	61,202
Total production of first eight months of 1890, .	18,353,849
Average production per day for 1890, . . .	75,600

Petroleum is obtained from the oil-bearing sands by means of wells, varying in diameter at different depths when completed, and cased with iron piping and tubing from 3½ inches to 7 inches, and in depth from a few hundred to 3000 feet or more. The strata in Pennsylvania and New York, which have been found to contain oil and gas in commercial quality, are all in the carboniferous and Devonian groups, and occur through a vertical range of about 3000 feet. The degree of productiveness in any particular locality can be ascertained only by actual test with the drill.

From the wells the oil is collected in small receiving tanks in which the measurements of production are made, and is thence carried by pipe lines to the large iron storage tanks of the pipe companies, which last have a capacity of 1,000,000 to 1,700,000 gallons. The transportation of crude petroleum from the field to the refineries is also largely done by means of pipe lines. A notable example of these lines is the one operated by the National

Transit Company, which extends from Olean, N. Y., to Bayonne, N. J., a distance of nearly 300 miles. This line consists of two 6-inch wrought-iron pipes laid side by side, and at intervals of about 30 miles are placed large pumps which reinforce those at the initial point, and make possible the transportation of the large mass of oil through the great distance named.

Incidentally it may be mentioned that the development of the petroleum industry has done a great deal towards bringing about the present high development of steam pumping machinery and the manufacture of wrought-iron pipe, two things of no small importance to the iron and steel industries to-day.

Petroleum is handled in the market by means of "pipe line certificates," issued to the producers by the pipe line companies, when the oil is taken from the operator's pipe. These certificates are sold in the open market or on the floor of the Oil Exchange.

Oil refining is an important industry in Pittsburg, there being a number of large refineries along the south shore of the Allegheny river.

Transportation.

Railroads.—The Railway system of Pittsburg is composed of integral parts of the three great trunk lines of the country, viz: the Pennsylvania Railroad, the Baltimore & Ohio, and the Vanderbilt corporations. The Pennsylvania controls not only its mail line from New York, with its branches, the West Penn, the Pittsburg, Virginia-Charleston, and the Southwestern Pennsylvania, but also the Pennsylvania Company's lines, namely, the Pittsburg, Fort Wayne & Chicago, the Cleveland & Pittsburg, Erie & Pittsburg, as well as the Allegheny Valley Railroad, directed to the north and northwest. Starting from the city also is the Pan-Handle system, whose objective points lie west and southwest. In a similar manner the Baltimore & Ohio Railroad has a complete connection with the Lake ports via the Pittsburg, Akron & Western, and Pittsburg, Cleveland & Toledo, and with the west and south via the Streets Run Route and Wheeling.

Pittsburg is the western terminus of the Pennsylvania Railroad, and the eastern terminus of all lines controlled by the Pennsylvania Company, an organization of similar name and in perfect accord with the Pennsylvania Railroad Company, but nevertheless a distinct organization.

The Baltimore & Ohio system reaches the city from the east by the Pittsburg & Connellsville road, now known as its Pittsburg Division, which joins the main line at Cumberland. Its western outlet is by the Pittsburg, Akron & Western Railroad, the transfer being made by the Junction Railroad, about nine miles in length, by which all rail and direct connections are completed to the west making a second trunk line through the city, and adding largely to it as a railroad centre.

The Pittsburg & Lake Erie Railroad, a line of about 175 miles in length, has connection with the coke region by the Pittsburg, McKeesport & Youghiogheny Railroad, and by the Monongahela Railroad with the southeast.

The total annual tonnage of Pittsburg during the year 1890, may be estimated at 27,000,000 tons. The total number of cars handled in Pittsburg in one month is about 110,000 with an average capacity of twenty-five tons and an average load of twenty tons. Many of the trains bringing ore from the Lake region are made up of thirty-ton cars and aggregate 1000 tons, drawn by a single locomotive.

The Rivers.—Through the Monongahela, the Allegheny, the Ohio and the greater rivers beyond, more than 20,000 miles of inland navigation are open to the steam craft of Pittsburg. Voyages of 4000 miles, to New Orleans and back, are a common thing; the farthest point reached by a Pittsburg steamer is Fort Benton, in the Missouri river, over 4300 miles away. The river shipping interests of Pittsburg comprise over 4000 vessels of some 1,700,000 tons displacement, and represent a capital of more than $9,500,000.

The average capacity of a coal boat is about 900 tons; that of barges, about 400 tons. Upon arriving at Pittsburg, from the mines above, the boats and barges are made into fleets, and about

10,000 tons actual burden, and are pushed by so-called stern-wheel "tow-boats" down the Ohio river to Louisville. At Louisville, fleets for New Orleans trade are made up of 20,000 to 30,000 tons and more, and are pushed down the Mississippi river to New Orleans, a distance of 2100 miles from Pittsburg, a cargo greater than the "Great Eastern" ever carried.

The system of navigating coal fleets in the Ohio and Mississippi is recognized to be the least expensive mode of transportation that is known. The actual cost, of course, varies from year to year, being greatly dependent upon the state of the rivers and the continuity of navigable waters. Upon an average, however, coal is sent from Pittsburg to New Orleans and the empty boats returned for less than one-tenth of a cent per ton per mile.

Manufactures.

Iron and Steel.—The commencement of the manufacture of iron in western Pennsylvania must be placed in the year 1790, when the first furnace was built in that part of Pittsburg now known as Shady Side Station, on the Pennsylvania Railroad. Seventy years elapsed before the second furnace in Allegheny county was built; that was the Clinton furnace of 1859.

The first iron furnace west of the Allegheny mountains was erected in Pittsburg in the year 1802, on the ground now occupied by the city post-office. This foundry became of considerable importance in later years by furnishing the national government with guns and munitions of war in large quantities. In 1816, the Juniata Wire and Rivet Mills were established, and in 1824, the first rolling-mill, known as the Juniata Iron Works; this last is still in operation, and is one of the leading iron works of the city. Other works followed in quick succession until Pittsburg became, as it now is, the chief point of production in the United States for the heavier forms of iron and steel.

There are now 21 blast-furnaces in Allegheny county, 33 iron mills and 27 steel mills. The output of these works for the year 1889 was as follows:

	Tons.
Pig-iron, ...	1,293,435
Rail, bar, angle, rod and hoop iron, .	499,044
Sheet and plate iron, ...	139,206
Nails, ...	200
Total manufactured iron,	638,450
Crucible steel ingots, ...	55,831
All other steel including Bessemer, .	1,049,742
Total steel,	2,744,023

The raw material consumed in making the pig-iron was as follows:

	Tons.
Ore, ...	2,500,000
Coke, ...	1,325,000
Limestone, ...	675,000
Total,	4,500,000

Besides the pig-iron manufactured in this city, most of which is consumed here, there is annually brought here for manufacture into higher forms an amount estimated at not less than 1,250,000 tons.

From these figures it appears that the production of Pittsburg in iron and steel is $18\frac{1}{2}$ per cent. of nearly one-fifth of the total production of the United States. The capital represented by the iron and steel industries of this city is approximately $51,522,000. On the average, 48,875 hands are employed.

The foundry business, which is not included in the above, deserves mention. The total cupola capacity of Pittsburg foundries is about 200,000 tons and they consume 125,000 tons of pig-iron annually, employing 3500 hands. The value of their yearly production is nearly $7,000,000.

Coke.—In speaking of the natural resources of western Pennsylvania, the character of the coal surrounding Pittsburg has

already been mentioned. This coal has proved itself specially adapted to the manufacture of coke. The Connellsville region, ranking as one of the two greatest coke regions in the world (the other being that of Durham, England), lies from 40 to 70 miles southeast of this city. This region is about three miles in width by fifty in length.

Connellsville, the town from which the region takes its name, has a population of about 5000 and is situated on the right bank of the Youghiogheny river, in the northern part of Fayette county. It is the centre of the Connellsville coke region, which stretches away to the north and south, a distance of 15 to 20 miles each way. It lies at the foot of the mountains, and the country around abounds in native iron ore, limestone and white sandstone, as well as coking coal. This is the basin of the Connellsville vein, as coal shafts have demonstrated, and the product here made is the best in the market. Three lines of railroad pass through here, viz.: The Pittsburg Division of the Baltimore and Ohio system, the Southwest Branch of the Pennsylvania system, and the Pittsburg, McKeesport and Youghiogheny road, a branch of the Vanderbilt system.

The seam of coal from which the coke supply is drawn is geologically the same as the Pittsburg seam, but differs from it in being of greater value for coke. The oven used in the Connellsville region is exclusively the Bee Hive oven, and the number of ovens in the district on the 1st of September were 15,223, of which 12,574 were in blast, and besides which 1535 additional ovens were being built. The output of coke for 1889 was 5,825,826 tons, the shipments were 326,220 cars, and for the first eight months of this year the shipments amounted to 4,090,893 tons.

The first successful application on a commercial scale of coke to blast-furnace practice made in this country was made in Pittsburg, and that only thirty years ago, when the use of coke was adopted at one of the leading furnaces in this city.

Notes on Works Visited.

Edgar Thomson Steel Works, Carnegie Bros. & Co., Ltd.—These works are at Bessemer Station, on the north bank of the

Monongahela river, 12 miles above Pittsburg. They consist of a blast-furnace plant, a Bessemer steel works and a mill for rails and structural shapes. The blast-furnace plant comprises nine furnaces, two of which are 90 feet high by 22 feet in diameter, and 33 hot-blast stoves. The annual capacity of the plant is about 600,000 tons, consisting of Bessemer pig-iron, spiegeleisen and ferro-manganese.

The sole fuel is Connellsville coke.

The Bessemer steel plant comprises 4 ten-gross ton converters, 6 pig-iron cupolas, 4 spiegel cupolas, 22 Siemens heating furnaces, one three-high 38-inch blooming mill, one shear and 1 three-ton hammer for shearing and clipping blooms, one 23-inch and one 24-inch three-high rail trains, with hot saw and finishing machinery. A forge, containing one 6-ton hammer, 2 heating furnaces, with necessary smith and machine shops is attached.

The daily capacity in double turn is 1300 gross tons of ingots, 1050 gross tons of rails, and 300 gross tons of billets.

The only fuel used in heating furnaces and under boilers is natural gas.

Oliver & Roberts Wire Company, Ltd.—This company's plant lies on the south side of the Monongahela river, within the city limits of Pittsburg. Wire rods is the exclusive product of the mill; 40,000 tons is the annual output, all of which is drawn into wire by the same company. The plant consists of four trains of rolls—two 9-inch, one 12-inch, one 18-inch, and 13 heating furnaces.

The fuel used is natural gas.

Oliver Iron and Steel Company.—The lower mills of this company are situated at Woods Run Station, Allegheny City, and the upper mills on Tenth and Fifteenth streets, south side. Operations were first begun in 1863. The plant of the two mills consists of 102 single puddling furnaces, 30 heating furnaces, 14 hammers and 19 trains of rolls, five 8-inch, three 10-inch, four 16-inch, four 20-inch, one 25-inch, one 32-inch, and one 30-inch universal. The product is plate, angle and structural iron and steel, skelp iron, light T-rails, bar iron, etc. Part of the iron is used in the production of wrought-iron hardware, consisting of

bolts, nuts, washers, hinges, etc. The annual capacity is 120,000 net tons. A steel plant containing two 2-ton Clapp-Griffiths stationary converters, for the production of Bessemer steel for miscellaneous uses, was added in 1884. Annual capacity in ingots is 48,000 net tons.

The fuel used is natural gas exclusively.

Crescent Steel Works.—These works lie on the east bank of the Allegheny river. They make a specialty of fine tool steel, having a yearly capacity of 12,000 tons of the same. They comprise 32 heating furnaces, 6 annealing furnaces, 9 trains of rolls, one 60-pot, two 30-pot, and two 24-pot Siemens steel melting furnaces, and 18 hammers. In 1889 a small Bessemer plant consisting of two 2-ton converters was added. The product of these works comprises hammered and rolled bar steel and cast spring and edge tool steel. In addition to the above, there is a shop for making iron for the company's own use, a drill rod shop, a wire shop, and a shop for making coiled springs.

Natural gas, coal and coke are used as fuel.

Lucy Furnaces, Carnegie, Phipps & Co., Ltd.—These furnaces are at Fifty-first street. There are two stacks, each 75 feet by 20 feet, and seven Whitwell stoves. The ore used is principally Lake Superior. The product is Bessemer, forge and foundry pig-iron, and the total capacity is 150,000 net tons.

Carbon Iron Works.—This company's plant is on the east bank of the Allegheny river. It was built in 1863 and rebuilt in 1888. It now comprises 4 Siemens heating furnaces, 7 direct air-heating furnaces, 16 reducing furnaces, for making iron by the direct process; one puddling mill with rotary squeezer, two 30-gross ton and two 15-gross ton Lash open-hearth furnaces and three trains of rolls, one guide mill, one 16-inch mill and one 22-inch universal mill, 36-inch wide. The annual capacity is 40,000 tons, consisting of plates and bars for structural and general merchant work.

Spang Steel and Iron Company, Ltd.—This company's plant is located at Etna Station, on the west bank of the Allegheny river, and was built in 1880–81. It comprises three 10-gross ton Siemens-Martin open-hearth steel furnaces, 7 heating furnaces, 1

hammer and 4 trains of rolls, one 30-inch bloom, one 30-inch universal, one 18-inch bar, and one 112 x 31-inch plate roll.

The product of the works is about 30,000 tons annually, consisting of steel, boiler, ship and tank plate, and machinery and spring steel. In 1886–87 two 3-ton Clapp-Griffiths steel converters were added.

The Keystone Bridge Works was established in 1860 by Messrs. Sheffler & Piper, and was organized as a company in 1865. The works cover some seven acres at Fifty-first street and Railroad. The plant consists of a full equipment of the most improved bridge building machinery, The annual output averages 16,000 tons of finished bridge material. The number of hands employed will average 600—about 480 in the shops and 120 outside.

Among the structures built by this company are the St. Louis bridge over the Mississippi, claimed to be the largest steel-arch bridge in the world, having two spans of 515 feet length, and one 520 feet; the Baltimore and Ohio Railroad bridge across the Susquehanna, at Havre de Grace, 6000 feet long, two of whose spans are 520 feet length; the train-shed of the Chicago, Milwaukee and St. Paul Railroad, at Milwaukee; and the Ohio Connecting Railroad bridge, described elsewhere.

The company is now at work on over three miles of elevated railroad for Chicago, and the "Winnow Bridge," over the Missouri at Kansas City, and other structures of various importance.

The Pittsburg Reduction Company—Manufacturers of Aluminum.—The Pittsburg Reduction Company, on Smallman street, between Thirty-second and Thirty-third streets, Pittsburg, was organized in 1888, and is the only concern in the United States manufacturing pure aluminum. The first experimental plant of the company consisted of one Westinghouse standard engine of 125 horse-power, two 60 horse-power tubular boilers, and two 1000 ampere 25-volt Westinghouse dynamos. These dynamos run in parallel, and supply a current to two pots in series, each of which takes ten volts. The output of this plant was 50 pounds of pure metal per day.

In the early part of the present year, an additional plant was built, consisting of two Westinghouse 200 horse-power compound

engines, a boiler capacity of 624 horse-power, two dynamos, specially designed by the United States Electric Light Company, of 2500 amperes and 50 volts each. These dynamos supply a current to five pots in series. The present total output of the works is 375 pounds per day.

Plans and specifications are now beng prepared for a new plant to have a capacity of not less than five tons per day, to be built in the natural gas and coal region of Pittsburg.

The Pittsburg Reduction Company manufactures under the patents of Charles M. Hall, which cover the electrolytic reduction of the oxide of aluminum by a direct and continuous process.

In Machinery Hall, at the Pittsburg Exposition, the Company has an exhibit showing a few of the uses to which the metal so far has been applied.

Pittsburg Plate Glass Company.—This company was organized in 1880, as the New York City Plate Glass Company, and reorganized in 1882 under its present name. The plant of the original company consisted of works at Creighton, on the West Penn Railroad, 34 miles from Pittsburg, with a capacity of 60,000 square feet of glass per month. The new company set immediately to work to increase their facilities by building new plants and making additions to the old. In 1886, new works with a capacity of 140,000 square feet were finished at Tarentum, three-quarters of a mile beyond Creighton, on the same road. In the early part of this year, the largest and best-equipped works of the company were completed at Ford City, on the Allegheny Valley Railroad, with a capacity of 200,000 square feet per month, and at the same time the capacities of Creighton and Tarentum were increased to 120,000 square feet and 175,000 square feet per month respectively. The plant at Ford City works will have a capacity of 400,000 square feet per month. The present capacity of the company's three works is 500,000 square feet per month, or, 6,000,000 per year.

The equipment of the company is twelve furnaces, casting two hundred and forty pots; ten grinders and twenty-one polishers, at Creighton; sixteen grinders and thirty polishers at Tarentum;

sixteen grinders and sixteen polishers at Ford City; the last to be duplicated in the extension; 600 men are employed at Creighton, 750 at Tarentum, and 1100 at Ford City. Around each plant are numerous dwellings built for employees by the Company. Ford City has 500 acres laid out in town lots.

Ripley & Company's Glass Works.—These works are on the south side of the Monongahela river. The equipment consists of twenty-five melting-pots, five "glory-holes," and a large quantity of specially designed machinery. The yearly product amounts in value to about $250,000, and consists chiefly of fine moulded ware of high grade. About 250 hands are employed. The fuel used is natural gas.

Miscellaneous.

Bridges.—Pittsburg's fifteen bridges show a great variety of bridge structure. There are two old wooden Howe truss bridges across the Allegheny, and one stiffened arch Howe truss across the Allegheny at "the point," another across the Monongahela at Tenth Street, and a wooden-braced arch bridge over the Allegheny at Sixteenth street. Across the Ohio, a few miles below the city, is the Ohio Connecting Railroad bridge, a single intersection Pratt truss bridge, with secondary trussing.

Across the Monongahela at "the point" is a stiffened suspension bridge. Over the same river, at Smithfield street, is a double bow-string or lenticular bridge of two trusses, with eye-bars rolled direct from steel blooms by the Kloman process; and further up is the Pan Handle Railroad bridge, an iron-deck bridge with two through spans over the channel, all of double intersection trussing. At Jones & Laughlin's, Limited, is the Monongahela Connecting Railway bridge, an ordinary pin-connected Pratt truss. On the Allegheny side there comes, first, after those already mentioned, the Sixth street wire-rope suspension bridge; the Seventh street stiffened suspension bridge, the chains of which are made of modern American iron eye-bars; the Ninth Street single intersection Pratt truss bridge, with secondary trussing, which is now being built in place of an old wooden bridge; the steel bridge of

the Junction Railway at Thirty-third Street; and the iron bridge, with Phœnix columns, at Etna.

In order to facilitate rapid transit from city to city, and from the north side of Pittsburg to the south side, two bridges over the Allegheny and Monongahela respectively will have street-car tracks separate from the carriage-way. These are the Ninth street bridge, which will be built with four tracks, and the Smithfield street bridge, which is being widened to accommodate a third roadway.

Rapid Transit.—With its numerous traction and electric car lines, Pittsburg may boast of as complete a system of local rapid transit as any city in the Union. Among the most prominent operating companies are the Citizens' Traction Company, the Pittsburg Traction Company, and the Pittsburg and Pleasant Valley Passenger Railway Company.

The Citizens' Traction Company has 12.98 miles of cable, in three lengths, over one main line and one branch. The longest distance covered between terminals is 5 miles, from Sixth street to East Liberty, along Penn avenue, occupying thirty-three minutes.

The Pittsburg Traction Company has 10½ miles of cable, also in three lengths. Two of these lengths being in the residence part of the city, out on Fifth Avenue, move at the rate of 12 miles an hour; the third, in the business part of the city, has the speed of 6½ miles an hour. The distance between terminals, from the foot of Fifth Avenue to East Liberty, by way of Fifth Avenue, is 5¼ miles, which occupies thirty-three minutes in passage; 25,000 passengers are carried by this line daily.

The Pittsburg and Pleasant Valley Company operate an overhead electric line. Its total length of track is 25 miles; its longest line is 4½ miles; the speed of the cars is from 5 to 12 miles per hour, according to the grade of the line at various localities. The number of passengers carried daily is 20,000.

Inclined Planes.—Pittsburg possesses a number of remarkable inclined planes, which are very necessary to rapid transit in a city of so numerous and steep bluffs as those of Pittsburg. Three of

these inclines lead up to the bluffs on the south side, and one of the three is said to have a steeper fall than is to be found on any other incline without cogs. Two inclines run up the central hill or table land of Pittsburg,—one from the Allegheny River side and the other from the Monongahela side. The former, called the Penn Incline, is particularly remarkable from the manner in which its tracks are led down over the top chord of the bridge at its foot. All of the inclines are of iron truss work, and are good pieces of engineering.

Slackwater Navigation.—The river coal-trade of Pittsburg originates in the valley of the Monongahela River, above the city. The river has been improved, by means of locks and dams, to such an extent that it is navigable for steamers, coal barges and coal boats, averaging from 6 to 8 feet of water, throughout the year, with the exception of about two weeks, during which time it is usually closed by ice. The slackwater system extends a distance of 102 miles, within which there are nine dams, with an average lift of 10 feet. The four lowermost dams are provided with double locks, the length of the pools averaging something more than 11 miles. Of the nine dams, seven are owned by a company operating under the Pennsylvania State laws, and two (being the two uppermost) have been recently built by the United States Government.

Davis Island Dam.—Four miles below the city the United States Government has recently completed the first of a series of adjustable dams—of the Chanoine wicket system—for the improvement of the Ohio River. The dam is lowered to pass coal fleets in time of freshets. It has one lock 500 feet long by 110 feet wide, at present the largest steamboat lock in the world. The cost of this dam, which has been of great value to the port of Pittsburg, was $980,000.

Pittsburg Exposition.—It was seven years in the latter part of last month since the old Exposition building was burned down. The present buildings for the Pittsburg Exposition Society on the point between the rivers, or rather along the bank of the Allegheny, were finished in the summer of last year (1889). The present exhibition is the second that has been made in the new buildings. The

net profits of the first year's exhibits, namely, that of 1889, was $59,000. That the results of the Exposition were considered successful not only by the Society, but by the exhibitors also, is evident from the character of this year's display.

ELEVENTH ANNUAL MEETING.

Pittsburg, January 20th, 1891.

The eleventh annual meeting of the Society was held on the evening of January 20th, in the parlor of the "Academy."

President W. Lucien Scaife occupied the chair and A. Dempster was elected Secretary *pro tem.*

The minutes of the last annual meeting were read and approved. The reports of the Treasurer and Secretary were read and approved, as also those of the Library and Program Committees and the Committee on Roads—which last was presented by title—and on motion, the Committee continued.

REPORT OF TREASURER

For the Year Ending January 20, 1891.

Receipts.

1890. January 17.		
Balance,	$280.48	
Dues for year ending Jan., 1889,	20.00	
" " " 1890,	105.00	
" " " 1891,	1250.00	
" ½-year ending Jan., 1891,	30.00	
" " " "	5.00	
Insurance premium refunded,	34.72	
Extra copies of papers sold,	5.10	
		$1730.30

Expenditures.

Printing and Binding,	$511.18	
Rent of Rooms,	352.00	
Salary of Secretary,	200.00	
Postage and Office Expenses,	163.40	
English and American Periodicals,	102.25	
German Periodicals,	50.24	
Stenographic Reports,	45.00	
Commissions on Collections,	42.37	
Periodical Case,	40.30	
Carpets, making, laying, etc.,	32.50	
Moving Expenses,	30.00	
Painting, Glazing, etc.,	15.95	
Road Committee, Expenses at Harrisburg,	20.42	
Dictionary Holder,	5.00	
		1610.61
Balance,		119.69
		$1730.30

Respectfully submitted,

A. E. Frost,

Treasurer.

REPORT OF SECRETARY

For 1890.

On January 21, 1890, our roll of active members numbered	336
Admitted during the year 1890, ...	46
Making an aggregate of	382
Members resigned since last report, ...	12
Leaving on our rolls, ...	370

Ten monthly meetings were held during the year, which were attended by 412 members and visitors, averaging $41\frac{2}{10}$ to a meeting.

Eleven papers were read, of which two were retained by their authors and do not appear in our published proceedings:

January 20th. J. A. Brashear read a paper on "Refinements of Modern Measurements."

February 18th. A. Dempster read the report of the "Proceedings of the Convention in Harrisburg," called by the "State Board of Agriculture," to discuss the change in the State laws affecting the public roads, which convention he had attended as our delegate.

Mr. Dempster also read a paper on the "Road Problem."

March 18th. L. B. Stillwell read a paper entitled "Public Safety and the Distribution of Light and Heat by Electricity."

April 15th. W. C. Quincy gave a talk on "Baltimore and Ohio R.R. Engineering Before and After the War."

May 19th. The report of the "Committee on Affiliation" was read.

M. I. Becker read a paper entitled "A Temporary Bridge Support."

June 17th. A. Kirk offered resolutions in reference to the "Herr's Island Dam," asking the government to build a "movable dam," which was adopted.

Phineas Barnes addressed the meeting on "Sundry Rolling-Mill Appliances."

September 16th. E. P. Allen read a paper on "Pittsburg and its Resources."

October 21st. The report of A. E. Hunt, our representative to the Engineers' Meeting in Chicago, to arrange for the International Meeting in 1893, was read.

J. W. Langley read a paper on "European Bessemer Practice in Small Converters."

November 18th. Charles Hyde read a paper on "Some Hydraulic Mill Appliances."

Thomas P. Roberts read a paper on a theory of the "Origin of the Cleavage Planes in Sandstone."

December 16th. H. B. Hibbard read a paper on "Some Defects in Open-Hearth Furnaces."

One of our original members, in the organization of the Society, Mr. Charles Ackenheil, engineer, who had attained an enviable position in the profession, resigned his membership in the early part of January ulto., and a few days after its acceptance he was killed in a railroad accident on the P. & B. Railroad, 50 miles north of Baltimore. Although not a member at the time, he had been so long a distinguished one, that I thought it proper to make this minute of his death and our regret at the calamity.

S. M. Wickersham,
Secretary.

REPORT OF LIBRARY COMMITTEE.

The Committee on Library begs leave to present the following report of progress for the past year:

Since the last annual meeting the books added to the library were as follows:

"Report of Mining Industry of New Zealand." 1890.

"Annual Report of Chief of Engineers, U. S. Army." 1889. 4 vols.

"Report of International American Conference relative to an Intercontinental Railway Line." Washington, 1890.

"Transactions of the American Society of Mechanical Engineers." 1889. Vols. 10 and 11.

"Report on the Substitution of Metal for Wood in Railroad Ties." E. Tratman, U. S. Department of Agriculture. 1890.

"Annual Report, Interstate Commerce Commission." 1889.

"Reports of the U. S. Coast and Geodetic Survey, 1865 to 1887." 23 volumes.

"Charts of Magnetic Lines, U. S. Coast and Geodetic Survey."

"Report of Chief of Ordinance." Washington, 1889.

"Report of the Director, Smithsonian Institution." 1887.

"Minutes and Proceedings of the Society of Civil Engineers." London, 1889 and 1890. 4 vols.

"Report of the New Jersey State Board of Health." 1889.

"Transactions, American Institute of Mining Engineers." Vol. 18. 1889.

"Description of the Edgar Thomson Steel Works and Blast-Furnaces." 1890.

"Transactions of the Technical Society of the Pacific Coast." 1884–1888. 1 vol.

"Report of U. S. Board appointed to test Iron and Steel and other Metals," 1881, 1883, 1884, 1885, 1886, 1887. 8 vols. in all.

Circulars of Information of the U. S. Bureau of Education. Washington, D. C.:

—"History of Education in North Carolina." C. L. Smith. 1888.

—"History of the Federal and State Aid to Higher Education in the United States." F. W. Blackman, 1890.

—"Rules for a Dictionary Catalogue." C. A. Cutter, 1889.

—"History of Education in Alabama, 1702–1889." W. G. Clark, 1889.

—"Teaching and History of Mathematics in the United States." F. Cajori, 1890.

—"Report on Indian Education." Gen. T. J. Morgan, 1889.

—"Education in Georgia." C. E. Jones, 1889.

—"Higher Education in Wisconsin." W. F. Allen and D. E. Spencer, 1889.

—"History of Education in Florida." G. G. Brush, 1889.

—"History of Higher Education in South Carolina. C. Meriwether. 1889.

"Report of Commissioner of Education for 1887–88."

"Power-Towing on Canals and Rivers." John M. Goodwin.

"Trade and Transportation between the United States and Spanish America." W. E. Curtis, 1889.

"Reports of the State Mineralogist of California for 1887, '88 and '89." 3 vols.

Reports of Second Geological Survey of Pennsylvania:

—"Dictionary of Fossils. 1889, 3 vols.

—"Report on Oil- and Gas-Fields of Western Pennsylvania." 1890.

—"Eastern Anthracite Fields." Part 3.
—"Southern Anthracite Fields." Part 2.
—"Northern Anthracite Field." Part 5.
Total number, 74.

The total number of journals, reports of societies, and other periodical publications received was 81. Of these 55 are sent in exchange for the proceedings of our own Society, 26 are received by subscription.

The average number monthly of visitors to the rooms during the first nine months of the year was 69. Since the occupation of the new rooms the number of visitors has largely increased.

The Library is now regularly open for the use of members until half-past nine o'clock P.M., daily, except Sunday. Our Committee has from time to time been asked to provide for the loaning of books from the library.

We have carefully considered the matter, and desire to renew our recommendation here, that the Society preserve intact the valuable collection of books and periodicals, by rigidly maintaining the rule which forbids the removal of any publications from the rooms.

FRANCIS C. PHILLIPS,
R. N. CLARK,
CHAS. DAVIS,
Committee.

The President then read his address, as follows:

GENTLEMEN: A well-known and prominent railroad official once remarked in my presence, apropos of a subordinate, that he had never known a college graduate who was worth anything. His last word was, however, much stronger, but less parliamentary than the one I have used, and was occasioned by some disregard of orders on the part of the subordinate.

While fully recognizing the value of a collegiate education for certain purposes, one is forced to admit that it does not properly train a young man to promptly and accurately obey the orders of a superior, but is apt to make him overrate, for a time, the value of his own judgment, and to underrate the extreme importance

of obedience and promptness in all business and engineering pursuits.

One of our own members, himself a remarkable example of financial success, has recently added his voice, through the public press, to the chorus of condemnation of college education as preparatory to a business or technical occupation. Although fully appreciating the value of polytechnic schools, he is persuaded that the college education of to-day is fatal to success in business.

As the subject is one of considerable importance, I shall take the liberty of offering a few thoughts that have occurred to me, not as a final solution of the difficulties surrounding it, but in the hope that some of our members may continue the discussion, and that this Society may become an ever-increasing factor in the success of its members.

We continually use the word success, but do all persons attach the same meaning to it? By no means. In fact, there are probably as many ideals of success as there are thinking people in the world. Moreover, a person rarely preserves the same ideal throughout life, and a man may think he has succeeded or failed in life, while the world may think just the reverse.

An apostle of culture may believe, with Hamerton, that "real success is simply the happy exercise and development of each man's faculties, whatever they may be." The man in advance of his time will find comfort in Heine's statement that "it is not merely what we have done,—not merely the posthumous fruit of our activity that entitles us to honorable recognition after death, but also our striving itself, and especially our unsuccessful striving, —the shipwrecked, fruitless, but great-souled WILL to do." Engineering success will also have a different meaning for many of us; but for the present we will assume that the successful engineer is one who designs and causes to be executed works of great and enduring value.

Let us see, then, what qualities and conditions lead an individual in one direction or the other. In ultimate analysis, I believe, there are at least four elements of success or failure in life. These are: Morality, or adhesion to right and duty; the judgment, or reasoning faculty; effective energy, or capacity for mental and

physical work; and environment, which includes inherited wealth and influence, friends and acquaintances, means of acquiring knowledge, and all other external aids or hindrances to success. Environment may be either favorable or unfavorable. If unfavorable, success must be attained by greater power and exertion of the other elements than where circumstances are favorable.

An engineering audience will pardon me for expressing these ideas in a quasi-mathematical form for the sake of brevity and precision. Thus:

$$\begin{matrix}\text{Success}\\ vs.\\ \text{Failure.}\end{matrix} = f(\text{Morality, Judgment, Effective Energy, Environment.})$$

This we will call the Equation of Success, in which all the terms are more or less interdependent. The greatest success is achieved where all the terms or elements are present in the highest degree and mutually favorable; the saddest failures where all are unfavorable in their intensity and mutual relations. There is every degree of success between these two extremes, caused by the deficiency or incompatibility of one or more qualities.

Genius and perseverance can overcome an unfavorable environment, but cannot dispense with the other elements of success, which we will now attempt to analyze more fully. Continuing, for the sake of brevity and clearness, our quasi-mathematical form, we have the Equation of Effective Energy, as follows:

$$\begin{matrix}\text{Effective}\\ \text{Energy}\end{matrix} = f\left(\begin{matrix}\text{Will-power, Skill, Mental and Physical Vigor,}\\ \text{Length of Life, Concentration, Perseverance,}\\ \text{Self-reliance, Self-control, Habit of Obedience.}\end{matrix}\right)$$

An examination will show that most of these qualities are inherited, but that they can be modified to a small extent by education. It seems to me that some recent writers on the subject have not sufficiently recognized the predominant influence of heredity in furnishing men with different natural powers which education can modify, but not create. A knowledge of one's weakness can be made an element of strength, and it is well for us to clearly

recognize the fact that all men are not born equal in natural ability, in order that we may not waste our time and energy in attempting the unattainable. Productive energy is universally recognized as essential to success. So much so that genius has been called simply an extraordinary capacity for work, and it has been recently said that "all men who have achieved great results have done so through excess of force in one direction. If we had an equal force in all directions we should do nothing."

As previously intimated, there is probably a maximum energy for each individual, but it may be concentrated either on useful objects leading to success, or dissipated in many ways leading to failure. If men would only treat their bodies and faculties with the same care and consideration that they give to a costly machine or engine, on which depends their daily subsistence, there would be less misery in the world. There should be, indeed, a mechanical science of man and of morals, of body and mind; and were such a science generally understood we should not so frequently see, for example, an engineer calculate to a nicety the strength of a bridge, while he is straining his own powers beyond the limits of recuperation; or a careful mill-owner keeping his plant in splendid working condition, while he permits his own bodily powers to deteriorate without taking the necessary steps to restore them, until body and mind are wrecked beyond repair. There are close analogies running through the realms of animate and inanimate nature, and we can derive great benefit by recognizing them and heeding their consequences.

To this end, we have need of good judgment, which is, perhaps, the most essential element of worldly success. Its "equation" might be stated somewhat as follows:

$$\text{Judgment} = f\,(\text{Intellect, Acuteness of the perceptions, Memory, Knowledge, Experience, Imagination, Mental discipline.})$$

For a successful engineer, the imagination must include inventive talent, and knowledge must embrace not only the theory and practice of engineering, but also the characteristics of men, and the

ability to manage them. It is unfortunately true that we frequently see engineers and business men who possess nearly all the qualifications for success, but who plod along in obscurity for want of this ability to properly direct the work of others, while men greatly inferior to them in other respects, attain to wealth and influence as managers and directors of affairs.

A college course does little or nothing toward teaching this art or science of managing men. On the contrary it sometimes tends to make students forsake converse with men for communion with books, to find satisfaction in thought, rather than in action. This may be well enough for those whose material wants are already provided for, but it is not the best preparation for a business or an engineering career. The latter careers require special knowledge and special abilities; and education for the purpose should be directed so as to supply the one and develop the other. Technical schools are a step in the right direction, and manual training schools still another advance. I am persuaded, however, that technical schools and colleges should have special courses devoted not only to political economy, but to the actual laws and customs of business ; to the complicated labor questions which almost daily arise, and to the fundamental principles underlying the selection and management of men for particular purposes. Young men are now forced to pick up as much of this information as they can, while engaged in the struggle for subsistence, whereas they might be saved many troubles and failures by early instruction in these matters as a preparation for that severer training which comes from actual participation in affairs.

A man should direct his energies in but few well-defined channels, but his intellect should draw its nourishment from many sources, in order that his judgment may have a firm and broad base. The successful man is always eager to absorb any information relating to his occupation ; and he is ready to throw its light immediately on any business problem that may arise. Almost every moment of our lives we have to decide between two or more paths which may ultimately lead to very different degrees of success and happiness. Good judgment will generally choose the right path, and will lead to comparative success in spite of occasional blunders,

even at important crises. Bad judgment will err at nearly every step, and will lead to failure in spite of occasional brilliant exceptions. We have only to glance at our Equation of Judgment to see how little the simple study of books has to do with training the reason, and why a man may be a prodigy of erudition, and yet prove a most unsafe counsellor in the affairs of life.

We may define the judgment as a process or mechanism for making inductions from facts and ideas recorded in the mind. The mechanism may be in perfect working order, but it will give false conclusions if the data were incomplete or imperfect; or the data may be correct, and yet the resulting conclusions more or less faulty, owing to derangements of the mechanism caused by improper mental or moral training, by passion or prejudice. Common sense is the result of induction of a normal intellect supplied with correct data as to the ordinary affairs of life. It might more properly be called uncommon sense, as it is probably never possessed in perfection by any individual. Unfortunately, nearly every person assumes just the contrary, instead of trying to discover his defects, or, as a physicist would say, his personal equation. Thus we are constantly witnessing the wreck of careers, piloted by blindly confident but really defective judgments, while our colleges are educating young men in a way better suited to monastic life, from which the system sprang, than to the active competition of our present civilization.

I certainly do not advocate the training of men to be narrow-minded workers, or money-making machines, propelled by avarice and ambition. On the contrary, I hold character and true knowledge as incomparably above the simple possession of superfluous wealth; and believe, with Canon Farrar, that "there is nothing more fatal than to throw life away in the effort to gain the means of living." But we have seen that morality, judgment and effective energy or action, are the principal elements of personal success in any pursuit; that they are interdependent; and that none can be neglected without detriment to the individual. Yet we find that our present systems of public and collegiate education give the chief place to memorizing, pay but little attention to good judgment, and ignore that greatest of social factors—action. As Emer-

son says, "life is not intellectual or critical, but sturdy;" and while honoring the cloistered geniuses of science and letters, we should not educate our rank and file of workers in the same way. On the contrary, every educational institution should endeavor first to teach the students to think independently, to judge quickly and correctly of the constantly recurring problems of every-day life, as far as the natural ability of each one will permit. In this way alone can such institutions fulfil the requirements of our present civilization in preparing young men for the active duties of life.

There is one other and very important term in our equation of success, viz., morality, or conformity to right and duty. Some of you may have been surprised at my statement that good judgment is perhaps the most essential element of worldly success, deeming that the first place should be given to morality. But meaning, as I do, by *worldly* success, the average ideal of success among the entire population of this or other civilized countries, it is unfortunately true that at the present time the average ideal is constantly attained by men deficient in the highest morality—that of pure Christianity. For all of us can recall examples of business or professional men who have been considered eminently successful by the world at large, although generally known to have failed to reach a high standard of integrity. Of course, this is no sufficient reason for our choosing worldly success in preference to true success. And by the latter I mean that which leads to a considerable increase in the sum of happiness and comfort in the world. Here, morality is the most essential element, and honesty and truthfulness count for more than wrongly acquired wealth or fame.

Engineers and business men are frequently tempted to follow the lower, in preference to the higher ideal. But fortunately in these as in other pursuits there are always men willing to sacrifice personal comfort and aspirations in following a high standard of duty. Such men serve to raise the average ideal of success by increasing through their influence and actions, the importance of morality as compared with the other elements of success.

Moreover, strong indications of a devotion to duty seem to me to pervade every great and successful work, whether of art or

science, engineering or manufacturing. We cannot help seeing that one or more men have consecrated their best thoughts and labors in the masterpiece, immortalizing themselves, it may be, but yet at the expense of valuable portions of life and energy.

In visiting some of the great cathedrals of Europe, I was struck by the frequent mention of several generations of engineers and architects who had devoted their lives to the same work, each trying to carry out the plans of his predecessors. The results of their self-sacrificing labors are great and enduring. The men are fraternally merged in their creations.

An engineering society like ours can do a great deal to foster this spirit of devotion to good work. It can increase the knowledge and reputation of its members by published transactions and personal intercourse. It can bring the man of thought in contact with the man of action, to the benefit of both. By elevating the ideals, improving the judgment, spurring the energies, and extending aid and sympathy among its members, our Society can materially assist each one of them in solving his equation of success in terms of the highest morality and greatest happiness.

W. LUCIEN SCAIFE.

After which the following officers for the ensuing year were elected:

T. P. Roberts, President, one year; A. E. Hunt, Vice-President, two years; James H. Harlow, Secretary, one year; A. E. Frost, Treasurer, one year; George S. Davison, two years; Thomas H. Johnson, two years.

After which the paper of the evening was read by Charles F. Scott, its subject being:

DESCRIPTION OF AN ELECTRIC COAL-MINING PLANT.

By far the greater part of the coal produced during the past year has been mined by the same methods that were in use a century ago. This is the more remarkable, as coal has been the prime factor in advancing the labor-saving machinery which has

revolutionized almost every other industry. There has been, however, a marked activity in this field of late, and the devices for mining coal which have been patented within the past year or two indicate by their surprising number and wide variety that much labor and ingenuity is being devoted to the problem.

All mining machines, whether boring, punching, drilling, sawing, scraping, with revolving cutter bars or travelling chains, are common in one particular,—each requires power. The power required to mine a ton of coal is but a trifle of the energy stored in it; but to get that power in suitable and convenient form is one of the greatest difficulties attending the mining problem.

The power must be in small, independent units, widely distributed; it must be easily portable from room to room; the apparatus must be light and compact, simple and strong, cheap and economical. The production of power by engines at the point where it is to be used is out of the question; it must be generated at one centre in large amount and distributed. It must be conveyed through dark, narrow, wet, winding passageways to various machines, and the machines themselves are constantly being moved about.

Transmission by shafting or wire-rope is entirely impracticable; the distances are too great for successful distribution by steam; compressed air has been most widely used, but this system is inefficient, pipes are costly and not readily transferred from place to place, and serious practical difficulties are reported by those who have used air-engines. Notwithstanding these drawbacks, air has been and is extensively and successfully used.

Electricity possesses many characteristics which are admirably adapted to meet the peculiar demands of power transmission in mines. On the other hand, the exacting conditions in underground work require apparatus of special design. The past success of this method of distributing power, and the promise it gives of future development doubtless account for the great impetus which mining machinery is receiving.

The object of the present paper is to give a description of the actual operation of coal-mining machines run by electric motors. The plant to be described has many features in common with

others which are working elsewhere, and the general conditions to be met in this kind of work, the class of machinery used, the success which has already been attained and the possibilities of future development, can readily be gathered from a study of its working. A point of special interest is that the Hercules Mining Machine is the product of Pittsburg brain, and skill and capital; that the electrical apparatus is of a new type and is supplied by the Westinghouse Company, and that the mine itself is within a few miles of the city. The mine is operated by the First Pool Monongahela Gas Coal Co., and is located at Willock Station on the Wheeling Branch of the Baltimore and Ohio Railroad.

Near the mine are several buildings. One is a sort of machine-shop with tools for fitting together or repairing the mining machines, sharpening bits, etc. Another building contains the boilers and a third is the power-house. In the latter are two horizontal engines, each belted to a dynamo. One of these is used for lighting the mine and the other furnishes current for operating the motors. Some lights are placed on the motor circuits, and if the plant were to be installed now, a larger dynamo for motors would supply lights also.

The dynamo is frequently regarded as a machine which is too delicate for a coal mine. It is really a simple machine, and requires only the same kind of careful and intelligent handling that a steam-engine demands. In the machine at Willock Station a cast-iron frame supports four inwardly projecting iron pole pieces, on which are placed coils of wire. The armature is built up of thin discs of iron, punched with T-shaped projections at the circumference. Around the teeth coils are wound. The wires, about the diameter of a lead pencil, are laid close together under the projections, and a V-shaped block of wood is driven in each groove to hold the wires in place. A brass cap is placed on each end of the armature. The two ends of the armature winding, and a third wire connected at the middle of the coils are connected to three smooth brass rings about 8 inches diameter and 1¼ inches wide at the end of the shaft. On these rings lightly bear copper brushes connected to wires leading from the machine.

The cast-iron frame gives the machine solidity and strength;

it surrounds and protects the revolving armature. The wires on the armature are entirely beneath the surface, and not liable to external injury. There is nothing about the dynamo corresponding to valves or gear-wheels, piston, or springs, and there are no compound motions or intricate fittings. There is but one motion; a simple, strong shaft revolves, and is in contact with nothing but its belt, its bearings and the brushes.

The revolution of the armature coils in front of the field magnets creates a tendency for current to flow first in one direction and then in the other. The current taken from this machine by brushes is an alternate current, analogous to a reciprocating motion. In many dynamos a device is provided for continually changing the brush contact from one wire to another, so as to keep the line current in the same direction. Such a current is a direct current, and is used in most motor systems.

The direct current required for exciting the field coils of an alternate dynamo is usually obtained from a separate machine, but in this dynamo an auxiliary winding on the armature is connected with a commutator, giving a current always in the same direction, which is sent through the field coils. The wires from the dynamo run to the switch-board. The instruments here are a switch for making connection to the lines into the mine; lead strips to melt if the current becomes too great; an ammeter for measuring the current; a voltmeter for indicating the pressure; a small hand regulator in the field circuit for adjusting the pressure by varying the field-current. The pressure is kept constant and the current is proportional to the number of motors working; just as in the case of a boiler supplying several engines, the pressure is constant and the amount of steam used varies.

The elements in an electrical system for the distribution of power are a source of power (in this case a steam-engine), a dynamo for transforming mechanical into electrical energy, conductors for conveying the electrical energy, and machines for reconverting it into mechanical form.

The conductor for electric currents possesses several points of superiority over ropes, belts, shafting or pipes. Wires are strong and not liable to break; they are small and easily put in place;

there are no joints or elbows to leak; they may be held in any position, carried in any direction, at any angle, around corners and by flexible cable. They may be taken from one place and used in another with comparative ease, and accidents from falling slate are easily and quickly repaired.

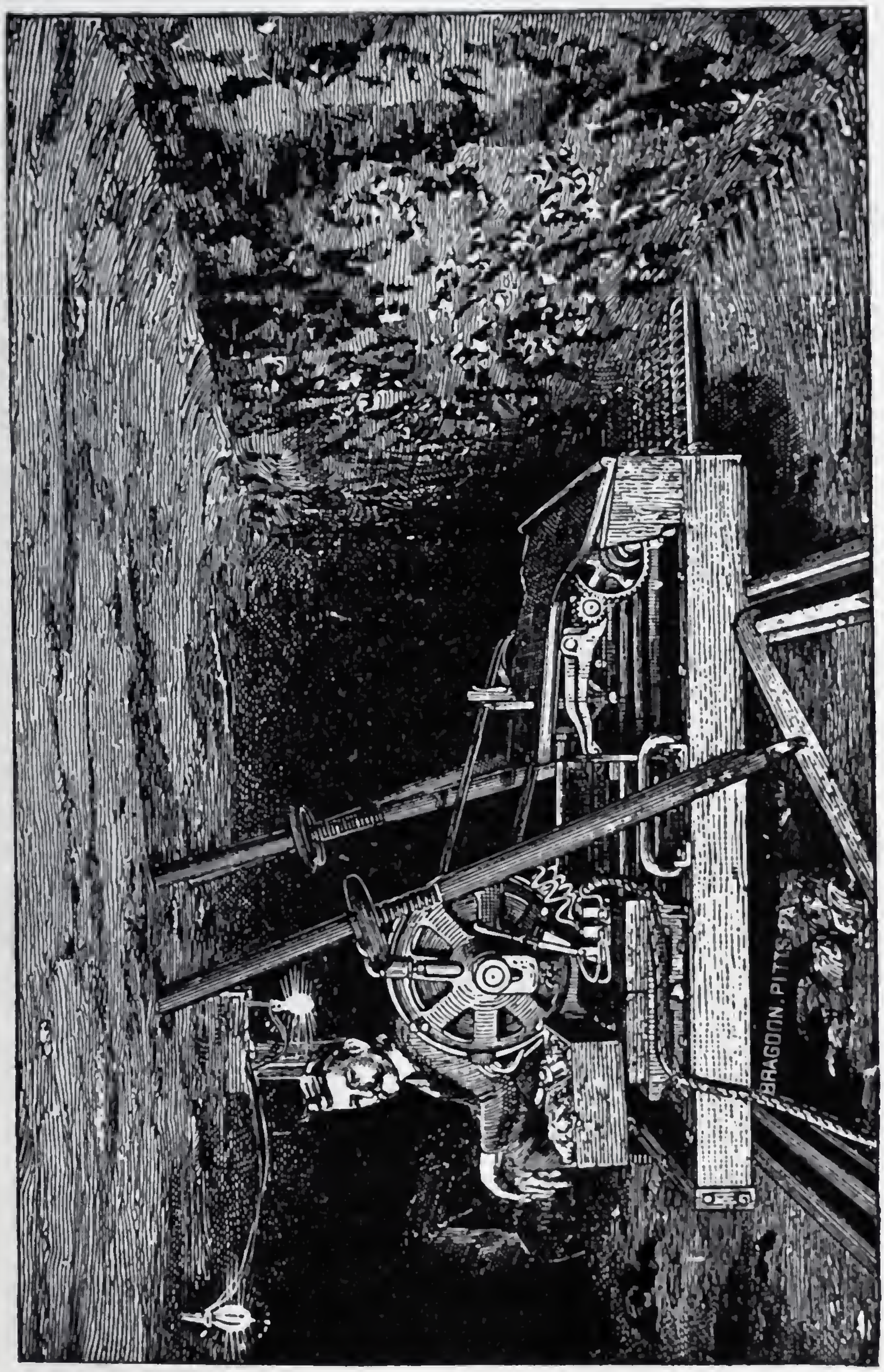
It is of course necessary that the wires be placed securely, and that they be well insulated from one another and from the ground. In the mines at Willock, the wires are rubber covered and are supported on insulators fastened to overhead beams, to posts or to wooden plugs driven in the roof or side of the entries.

Lines are carried along the main entry, and switches with safety fuses are placed at the entrances to rooms. From these switches wires extend down to near the point where the machine is to be placed. A flexible cable connects the wires to the motor.

An electric motor is a machine in which mechanical motion is produced by a current of electricity. There are two parts in which currents passed through coils of wire magnetize iron cores. One set of cores or magnets is stationary, and is called the "field;" the other is movable and is the "armature." The magnetic poles in the latter are so placed that the mutual action between them and the fixed poles causes motion. In the direct current motor, the current which magnetizes the revolving armature enters it from brushes bearing upon a commutator. The latter consists of many strips of metal, so arranged that as the armature revolves the brushes make contact with successive wires; although the armature may be in continuous motion, yet the poles formed by the armâture currents are always in the same position relative to the field poles; the result is a constant reaction between the two sets of poles producing a continuous rotation.

In the Tesla Alternate Current Motor the construction and action are quite different. This motor is cylindrical in form, with inwardly projecting poles on which coils are placed. Inside is an armature supported by bearings in the cast-iron brackets which cover the ends of the machine. The armature wires are laid in grooves and are well protected. The unique feature of this motor is that the ends of these wires are soldered together and have no

connection with external wires. The currents from the generator do not enter the armature, but simply pass through the coils on the fixed poles. As there is nothing inside the motor to be ad-



Tesla Motor Driving Hercules Coal-Mining Machine.

justed or looked after in any way, the whole motor can be enclosed; the openings in the end brackets may be covered with wire gauze; there is no moving part except the revolving armature, and the only external parts of it are the ends of the shaft, one of which

carries a pulley. The only accessory apparatus is a simple switch.

Those who are acquainted with the construction and operation of electrical machinery will appreciate the absence of a commutator. It is expensive to make, maintain and renew. It is the point requiring the most careful adjustment and attention, and yet is the source of more difficulty than all other causes combined. It is especially undesirable in a wet mine where there is flying coal-dust, rough handling and careless attendance.

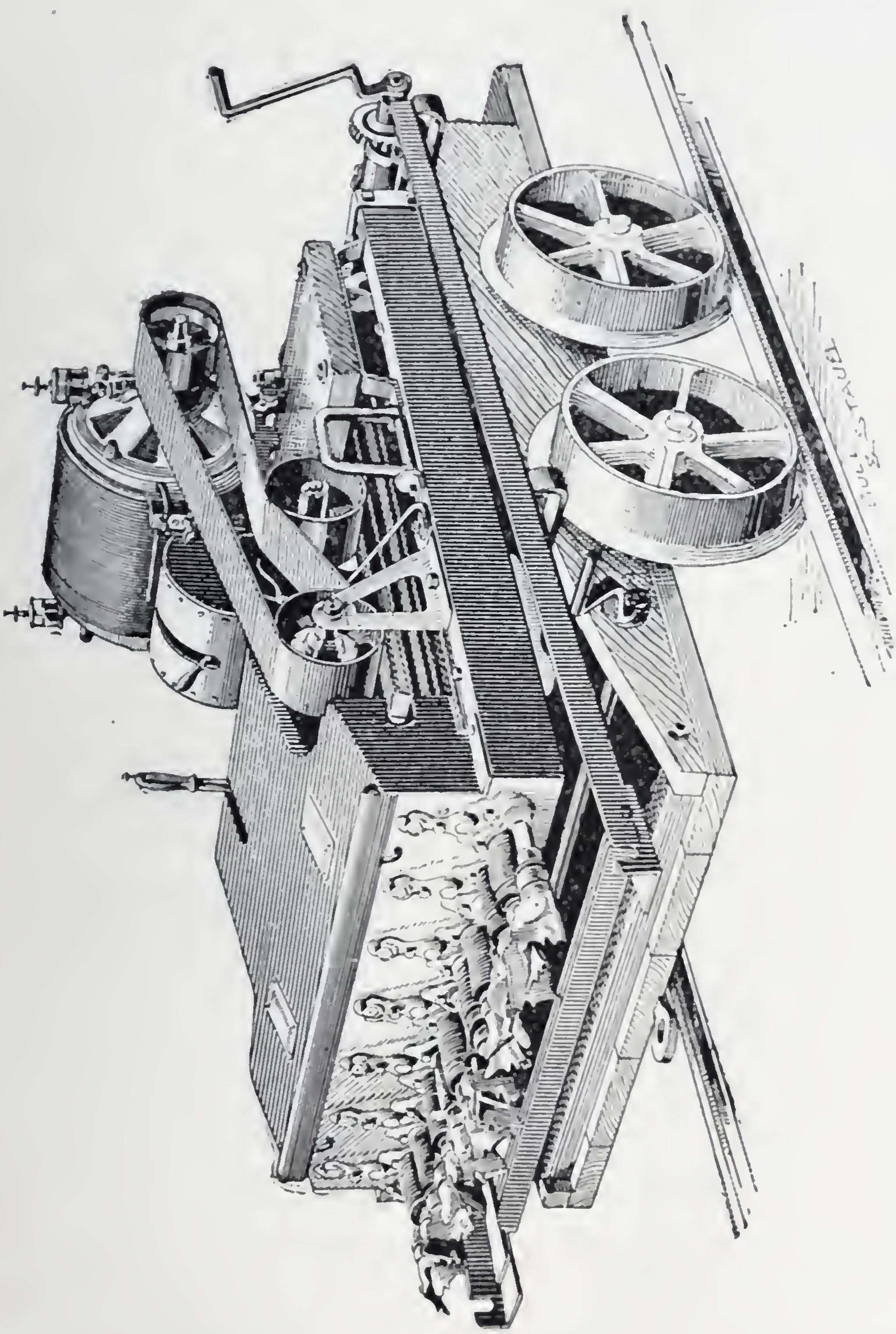
The electrical principles upon which this motor depends are as beautiful as the construction is simple. Three wires are used; they convey two distinct currents, which may be transmitted by four wires, two for each circuit, or by three wires where one is common to both currents. The currents in the two circuits are alternating, and reverse their direction 6000 times a minute. The only difference between the two currents is that one occurs a little later than the other; one is maximum, where the other is zero. The action may be graphically represented by two sine curves, one 90° in advance of the other. Horizontal distances represent time and the ordinates indicate the direction and intensity of the current. The coils on the motor poles are connected in two similar circuits, each containing alternate coils. The coils in each circuit are so connected that when current flows, half of the poles (the odd ones) become positive and the other negative. When the current reverses the poles change sign.

When, therefore, one of the currents is zero and the other is at its maximum every other pole is inactive, and those in the other circuit are magnetized alternately + and —. A moment later the conditions are changed. The inactive circuit becomes magnetized as the other was a moment before, and it in turn has no current flowing through it. It will be noted that the position of each + and — pole is at one side, the right for instance, of what was a + and a — pole in the other circuit.

The current in the second circuit dies away and the first becomes active again, but the current is now reversed and the poles which were + before are now —, and again each pole is to the right of what was an instant before a pole of the same sign in the

other circuit. The effect is a virtual shifting of the poles, very similar to the revolution of permanent magnets.

A peculiarity of the alternate current is that a current through a coil of wire will induce a current in an adjacent coil, although



separated by a considerable air-space. An iron core through the coils intensifies the action. The alternate current in the motor fields sets up currents in the armature coils, and the reaction between the armature and the shifting field-poles causes rotation.

The Hercules Mining Machine does its work by boring or drill-

ing. A number of revolving augurs or gang-bits placed side by side are fed into the coal, cutting away a narrow horizontal slot at the bottom of the vein. The frame of the machine is made of channel steel, and is 3 feet by 5½ feet. At the back end the motor is placed with its shaft across the machine. A belt from the motor-pulley drives a shaft at the other end of the machine. This shaft sets in motion several trains of small gear-wheels for revolving the bits and feeding them into the coal. At one point in the series are seven triple pinions. The middle pinion is driven and each of the others is geared to a steel pinion having a brass bushing with a square hole. Through the hole slides a square ¾-inch cold-rolled steel spindle about 4 feet long, the front end of which carries a head for holding the bit; these heads are held in place and kept in line by a cross-bar. The bits have two sharp points near the centre of revolution which advance into the coal, and a sharp cutting edge on one side bôres a hole about 3½ inches in diameter. The bits are placed side by side and overlap, cutting out the core, and making a clean slot in the coal instead of a series of round holes. The other ends of the long rods which carry the bits are held in a bar or carriage which extends from one side of the machine to the other, and is carried forward or backward by pinions at each end fitting in racks which extend the whole length of the machine. The power for feeding is transmitted through a friction cone or cup, between the metal surfaces of which is a cup-shaped leather washer. There are two such friction-cups, either of which may be thrown in action by a lever; one gives a slow advancing motion to the drills, the other draws them back rapidly. The friction connection allows the feed to be thrown on or removed suddenly irrespective of speed.

The friction-cup and the belt afford points for slipping if an exceptionally hard place in the coal be encountered. The triple pinion is an additional safety device. The high-speed gear is cut steel, but this pinion is cast-iron, and in case a hard foreign substance demands that something break, the more costly parts of the machine are protected by this pinion; it is cheap, and can be readily replaced without removing the machine from the mine.

Around the steel spindles which drive the bits are spiral springs

or extensible conveyors, which revolve and carry back the cuttings, and keep the slot clean. The first cost of the bits is small, and they are cheaply sharpened and easily replaced.

A coal mine is usually worked by driving a tunnel or main entry into the coal, and at distances of 160 yards on each side other entries leave the first. From these still other entries are driven at right-angles, 8 feet wide and 21 feet long; they are then widened out on one side to 21 feet, and kept at this width. The rooms are lengthened by undercutting the end or face and blasting down the coal with powder placed in holes drilled at the top of the seam. The rooms are spaced so that a 12-foot wall or pillar is left between them, and when the coal from the rooms is mined these pillars are removed, beginning at the back. These dimensions have been dictated by experience as the best for hand-mining, in which the undercutting is done with a pick.

In machine-mining the rooms are made 34 feet wide and the pillars 15 feet. This is practicable because of the greater rapidity with which a room is mined—the roof will stand the shorter time with fewer pillars.

Where a machine is used, it is placed at one corner of the room on rails parallel with the face of the coal and with its bits against the coal. The rails may lie on the ground, or may be raised so that the cutting can be done at any height or at any angle. When all is ready the operator turns the switch, the motor starts and the fourteen bits revolve. The feeding gear is connected by moving its lever, and the cutting begins. The machine does not require any holding or guiding; in fact the operator ordinarily busies himself in using his oil-can, looking after his tobacco pipe and arranging the jacks to hold the supporting rails in place ready for the next cut. Anything abnormal in the working is indicated by a change in the sound. When the cut, 3 feet wide and $3\frac{1}{2}$ feet deep, is completed, the reversing lever is moved and the bits are quickly withdrawn.

The machine is readily slid along on the rails to the next position, and is then ready for cutting again. This is repeated until the whole face of the room has been undercut. The machine

is then dragged on to a special truck by a windlass and is hauled by a mule to another room.

All the work, except this moving, is done by one man. The machine has been designed to be as light as possible, so that two men would not be required to handle it; otherwise it could be heavier and work faster. The decrease in time of cutting with a larger machine would not be clear gain, as more time would be required in shifting it about and transferring it from room to room. The gross weight of this machine is only 1140 pounds, and the extreme height of the present design is 28 inches.

In hand mining the miner lies on his side on the ground; the work is tedious and laborious; nothing is required but brute strength and the skill which comes by practice. Machine work is cleaner and less slavish; the man works in an upright position, exercises intelligence and may command better pay.

The introduction of machinery in any industry necessitates a readjustment of labor, and the temporary inconvenience which sometimes results prejudices workmen against new methods. The intelligent and far-seeing miner, however, must recognize that machinery has come to stay, and that his own interests will be in the long run advanced.

The effect of acquaintance with machinery is shown by the changed attitude of the men at this plant. The sentiment at first was that the thing should be thrown over the dump. Not long since, however, the boilers required repairs and work ceased for a time. The men preferred to wait for the machines rather than return to hand-mining. Within the past few weeks two of the men who have been running machines have made a contract to operate a new plant at a handsome reduction on hand-mining, and they depend upon additional saving for their own profits. There are now in this vicinity 400 men working in connection with mining machines of various kinds.

The important question to be determined is the bearing of mining machinery upon the cost per ton of merchantable coal. The immediate effect is a reduction in the cost of labor of under-cutting (which in hand-mining is about half the cost of placing the coal in pit-wagons) from about 40 cents to 10 cents per ton of

$1\frac{1}{2}$ inches coal; the cost of labor thus becomes 10 cents per ton for undercutting and 40 cents for blasting down and loading. This is on the basis of the wages paid to skilled miners. A competent man could easily look after several machines in the hands of unskilled men, and can direct the loading by cheap labor also. The boss and the laborers may both make good wages, and yet the lowering of the grade of labor required will result in an estimated saving of 25 per cent.

There are not enough skilled miners to meet the present demand. Almost every coal company in this region has experienced difficulty in securing men, and very recently a mine near Pittsburg was closed because miners could not be obtained for more than about two-thirds the normal output of over a thousand tons per day, and partial working was unprofitable. An increase in the intelligence of the skilled labor and the proportion of the unskilled, will do much to reduce the difficulty in obtaining men and in avoiding the disastrous conflicts between miners and operators. This is of such importance that the general manager of a large company said not long since, that he would be satisfied with a mining plant producing coal at the same cost per ton as hand-mining.

Machine-mining results in indirect gains, which will be evident when the method of working a mine is considered.

The miner with his pick finds an advantage in stealing away coal from the walls of his room; this weakens the supporting pillar and the weight of the roof sometimes crushes the remaining coal so that it cannot be removed. The machine does its cutting straight and leaves a perfect wall. About a year is required for working out a room the old way; about one-quarter of that time the new way. This lessens the tendency to settling of roof and crushing of coal in the pillars, thus increasing the output per acre.

Tracks for coal-wagons extend along all entries and into each room; for each of the latter a turnout or switch is required. For a given output per day the number of rooms of a given size required in hand-mining is four times as great as in machine-

mining. If the rooms cut by machines are one and one-half times as wide, the number of rooms worked by hand must be six times as great for the same daily output. One machine can serve three or four rooms; while cutting one the others are being blasted down and the coal hauled out. Therefore, if each machine-cut room is equivalent to six hand-cut rooms, and one machine is required for three rooms, then but three turnouts will be necessary for the daily output which would require six times that many, or eighteen, for hand-mining. The saving on the fifteen turnouts rendered unnecessary by each machine amounts, at $25.00 each, to $375.00. If the life of a turnout is about five years, one-fifth of this amount or $70.00 should be credited to each machine per year.

When wider rooms are used only two-thirds as many entries to rooms are required. If a machine mine its four rooms in about three months, the saving in that time will be, two 21-foot entries at a cost of $15.00 each, which is $30.00, or $120.00 per year.

The above figures have been furnished by a mining engineer and illustrate ways in which indirect saving may occur. The conditions in some mines may not admit of wider rooms for machines. In such cases the estimated saving in entries and turnouts would not result.

As a machine can cut a given number of rooms in so much less time than is required by hand the rate of shipments from a mine of given size can be enormously increased, which is sometimes of the greatest importance.

Another point is, that if fewer rooms are being worked for a certain output, less length of rails in the rooms and fewer posts are deteriorating.

By the current custom a miner receives pay for the coal which will not pass through a screen with bars 1½ inches apart. It is to the advantage of the miner to have little slack, but the company gains by the free slack, although it commands a less market price. On the other hand, the river operators prefer large coal, as they sell by the bulk in barges and the slack simply fills crevices.

But neglecting these arbitrary regulations and considering the question from an economic standpoint, that method of mining is

best which produces the greatest output of large coal per acre. In undercutting with a pick the miner cuts out about 18 inches at the face tapering down to 3 inches at the back, the greater part of which is fine coal or slack. The careless miner may not undercut far enough and shatter his coal greatly in blasting, causing still greater loss. The slot made by the machines is $3\frac{1}{2}$ inches. The difference, say 8 inches amounts to 600 tons per acre, which is slack by one method of cutting and good coal by the other. If the large coal brings in the market 40 cents more than small coal, the gain is $240.00.

This neglects the fact that some of the hand-mined slack would be left with the gob in the mine. The fewer pillars lost when the machine is used will also increase the output per acre.

The Hercules Machine was first operated by compressed air. In September, 1889, one was equipped with a Tesla Motor and after three months' trial a new generator and six new motors were ordered. This plant was started in April last. The station apparatus has been run by several engineers who had had no previous experience. The mine-boss reports that during the last sixteen months the work has been stopped on account of the dynamo but three hours, owing to the clogging of an oil tube. The motors, in the hands of ordinary men, have given but little difficulty. The requirements made on the first motor were increased until it was greatly overloaded, and the limit was found. The injury was easily repaired and it still does its normal work satisfactorily. The motors which began service last April have met with but one mishap of any note, and that was repaired in half a day.

Actual figures on the cost of operating and the quantity of coal which has been mined would not fairly represent a plant working at full capacity. The output of the mine has required the running of but three or four machines; motors are used for fans and pumps, and at times lack of railroad cars and other causes have decreased the output.

Figures, however, have been obtained for a very fair estimate of costs and profits.

The records of the work of machines during several months past show an average of $3\frac{1}{3}$ cuts per hour in the hands of new men, and about 4 with older operators; the average some days has been as high as 5. Each "cut" represents $10\frac{1}{2}$ square feet undercut.

The amount of coal overlying this area depends, of course, on the thickness of the seam of coal; it may be half a ton or several tons. In the present vein, 4 feet 2 inches thick, it is about 1 ton of $1\frac{1}{2}$ inch coal, or $1\frac{1}{3}$ tons "run of the mine." The output of large coal per machine is therefore 33 tons per day of 10 hours, or 66 tons per 20 hours. The latter will give most favorable results, as the output is doubled and some of the expenses, as turnouts and interest on investment are not increased. The less favorable 10 hours is the basis taken for the accompanying computations. The capacity of the present plant is seven machines.

The estimate is based upon boiler, engine, dynamo, wires, motors, machines and construction of a plant for operating 7 machines. The output of 7 machines, run 10 hours per day, each cutting $3\frac{1}{3}$ tons per hour, is 233 tons.

The daily expenses will be:

Oil, waste and fuel, ...	$2.30	
Wages of machinist, engineer, trackman, wireman, and man with mule, ...	12.00	
Deterioration on boiler, engine, electrical apparatus and wire (the repairs on dynamo and motors have been less than two-thirds of 1 per cent.), say 25 per cent. on $7500, . .	6.25	
Cost of repairs on mining machines, sharpening bits, etc. (mean of several machines several months, $2\frac{1}{8}$c. per ton), 233 tons, ...	4.96	
Cost of running machines, at 10c. per ton, .	23.30	
Cost of loading and blasting, at 40c. per ton, .	93.20	
Total daily expense, ...		$142.01

Indirect economy in machine mining:

Saving per day in marketable coal at $240 per acre (which can be cut in less than twenty-four days), ...	10.00	
Saving per day on entries at $120 per machine per year, ...	2.80	
Saving per day in turnouts at $70 per machine per year, ...	1.40	
Indirect saving, ...		14.20
Daily expense, less indirect saving, . . .		$128.81
Cost of hand-mining at 79c. per ton, 233 tons,		184.07
Saving by use of machines, per day, .		$55.26
" " " per ton, .		.23$\frac{2}{3}$
" " " per year, .		16,500.00

This profit is equivalent to interest on an original investment of say $15,000, at the modest rate of 110 per cent.

An estimate based on a plant run twenty hours per day, with a more moderate allowance for deterioration, a reduced cost of repairs on the mining machine (improvements are in progress which will simplify and strengthen it), together with a reduction of 25 per cent. in the cost of labor in cutting and loading (which alone would increase the profits 50 per cent.) would appear too visionary.

The saving of $16,500 is based on an output of but 233 tons per day, while something like 30,000 tons per day is loaded on Monongahela river boats, and the railroads carry no small portion of the total output from this region. The saving on the bituminous coal mined in this State would be over $8,000,000 per year.

It is far from the purpose of this paper to detract in any way from other mining machines or electrical apparatus,—it is rather to indicate the richness of the field that is open to all. Other plants may show equally favorable results. Each type of mining machine may be peculiarly fitted for certain kinds of coal; but the Tesla Motor and the Hercules Machine have proved beyond peradventure the success and possibilities of well-constructed,

simple, well-installed electrical apparatus and a mining machine which will do its work.

The discussion of this paper was postponed until the next regular meeting.

Two gentlemen here named were elected members of the Society : H. Plummer McClintock and Thomas B. McKaig.

The meeting adjourned at 10.30 P.M.

A. DEMPSTER,
Secretary pro tem.

FEBRUARY 17TH, 1891.

SOCIETY met in the parlors of the Academy of Science and Art, on February 17th, at 8 P.M.

Twenty-eight members present.

F. Z. Shellenberger was called to fill the place of the President, T. P. Roberts, who was detained by sickness.

The minutes of the January meeting were read and approved.

Charles A. Camp, E. E. Means, Emil Hallgren, W. H. Kemler, J. Branne, J. M. Deforth, E. K. Scott, James B. Hardie, and George Jewett Hicks, were elected members of the Society.

The Secretary read some correspondence which had passed between Professor Lewis M. Haupt, of the University of Pennsylvania, and Thomas H. Johnson, of this Society, regarding the plagiarism of one of the competitors for the prize offered for an essay on "*Roads and Roadmaking*," he having copied, *verbatim*, at least eight pages from the report made by the committee from this Society. After this the paper read at the previous meeting by C. F. Scott, was discussed by those present.

DISCUSSION OF PAPER ON ELECTRICAL MINING MACHINES.

C. F. SCOTT : I have prepared no résumé of the paper, but, at the president's request, will give a few items from it which may serve to open the discussion. The paper starts out with some general observations on the mining industry, and the application of ma-

chinery. The apparatus for supplying power must be simple and strong, light and compact. The production of power at the place of working is out of the question; it must be transmitted from a common centre through intricate passage-ways which prohibit the use of shafting, belting, or the ordinary means of transmitting power. Electricity meets many of the demands so admirably, that it has given great impetus to the mining-machine industry. Many who are not familiar with electrical machinery have an idea that it is complicated; requires an expert in its operation, and is very liable to get out of order. Various points about the construction of the dynamo are mentioned in the paper, showing that it is really a simple machine, while the history of its operation at this mine in the hands of actual miners, and not experts, has been highly satisfactory.

A description then follows of the principles and construction of electric motors. The point in which the motor used in the mine described differs from ordinary motors is that it is operated by an alternate current, in which the action is similar to a reciprocating motion, the current passing first in one direction and then in another. Electrical apparatus to be operated by the alternate current must differ very materially from that to be operated by the direct current. The difference has an analogy in mechanics in the varying proportions of parts designed for a uniform motion, or for a reciprocating motion, in which inertia must be considered.

The Hercules mining machine is a boring machine. Other mining-machines are based on the principle of punching— a bit is drawn back and instantly released, striking the coal. Another type has an endless chain, with teeth for cutting the coal Still others have a revolving cutter-bar, with bits placed upon it, which revolves and is made to advance in under the coal. Another machine is similar to a big saw. The Hercules machine has fourteen bits, placed side by side, which are caused to revolve and to cut in at the bottom of the coal. One cut of the machine gives a slot three feet wide, three and one-half inches high, and about three and one-half feet back under the coal. The machine is then withdrawn and slid along on rails, which are parallel with the face of

the coal, and the bits are then sent into the coal again, so that when the room has been completed its end is under-cut with a slot running across the whole face and three and one-half feet deep. The machine is then taken away to another room, and the coal is blasted down by powder placed near the top of the seam in holes drilled for that purpose.

A description then follows of the way in which coal is usually mined, entries running in the seam of coal, and from these side entries extend to rooms.

The rooms in hand-mining are usually 21 feet wide; in machine mining it is found practicable to work 34-foot rooms.

An interesting point in mining is, that in the hand-cut mines the entries to the rooms are made at one side of the room, and track runs along the side. When a pillar is to be drawn the coal at the back is dug out and hauled away on the track running along the side of the pillar. In the accompanying diagram the entry to the room is shown at the middle of the room. If the pillars are to be drawn, the entries are made at the corner of the room. The drawing is made here as it is at the coal mines now being worked. The pillars are so weak, and the roof is in such a condition that the pillars are not drawn, so that it makes it a little more convenient to run the tracks down the middle of the room.

Another advantage in machine mining, which amounts to very considerable, is the narrowness of the slot, which is made in the under cutting. When cutting by pick the miner has to have considerable room at the face of the coal in order to enable him to work back. The coal which he digs out is mostly fine coal, or slack, and does not command as high a price as large coal. The machine makes a narrow slot and saves the large coal. The difference is readily seen in the diagrams. The saving is computed to be about six hundred tons per acre, amounting to two hundred and forty dollars. This is the difference between that amount of coal in slack and in large coal, and the amount would be still greater than that if a part of that slack is left in the mine.

F. Z. Shallenberger: How much do you count as your yield to the acre?

C. F. Scott: About one thousand tons per foot, that is, five

thousand tons to the acre, taking the whole thickness of the seam. Other points to be considered are that fewer entries to rooms have to be made when there are fewer rooms. A large number of rooms necessitates more switches and turn-outs, a greater length of track, a greater cost in digging the entries, and an increased number of switches along the track. The track is harder to keep in order, and is more apt to become clogged up by cars on the numerous switches.

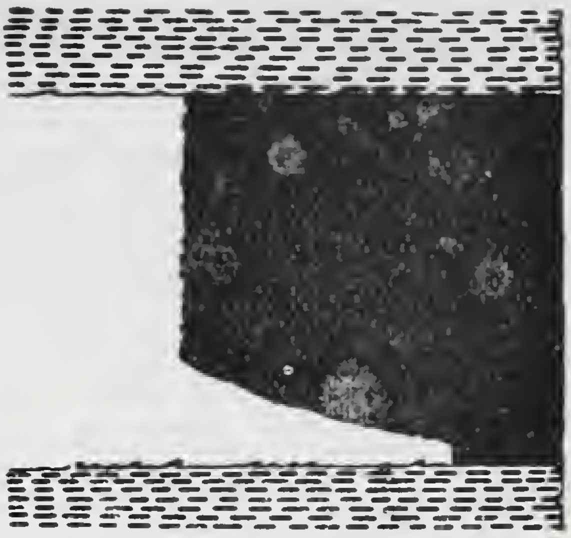
Mr. Scott here read from the paper the figures on the cost of operating a plant for an output of 233 tons per day, with the estimates on the indirect economies.

A point of advantage in machine mining is the fact that from a given area the coal can be mined much more rapidly. This sometimes becomes a very important point at certain seasons of the year; also, for a given output from a mine of indefinite extent it is necessary to open a much less number of rooms for machine mining than would be required in hand mining. This will decrease very much the cost of turnouts and switches, and the amount of territory in the mine which has to be kept open ready for operating.

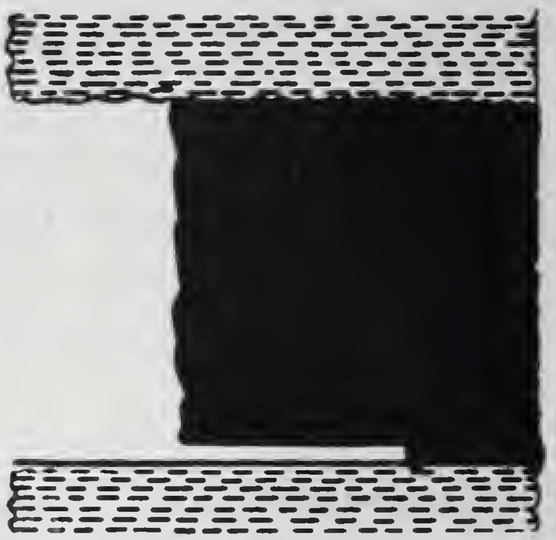
The purpose of the paper has not been to especially advertise this machine or electrical apparatus, but from a statement of what it has done to show the richness of the field that is open for this class of work. A coal man from the eastern part of the State was in the city last week. I met him accidentally. He said he was going out to see this mining machine work and that there was one point about the machine in which it differed from others. For many other machines, he said, large figures had been announced, but when they got to work it was found that the figures had to be materially reduced; but this machine had started in a very modest and humble way, and its figures right along had been on the increase and it was doing more than was claimed for it.

F. Z. Shallenberger: Is it one machine?

C. F. Scott: There are two plants in operation near the city and there are several machines running daily at the plant described.

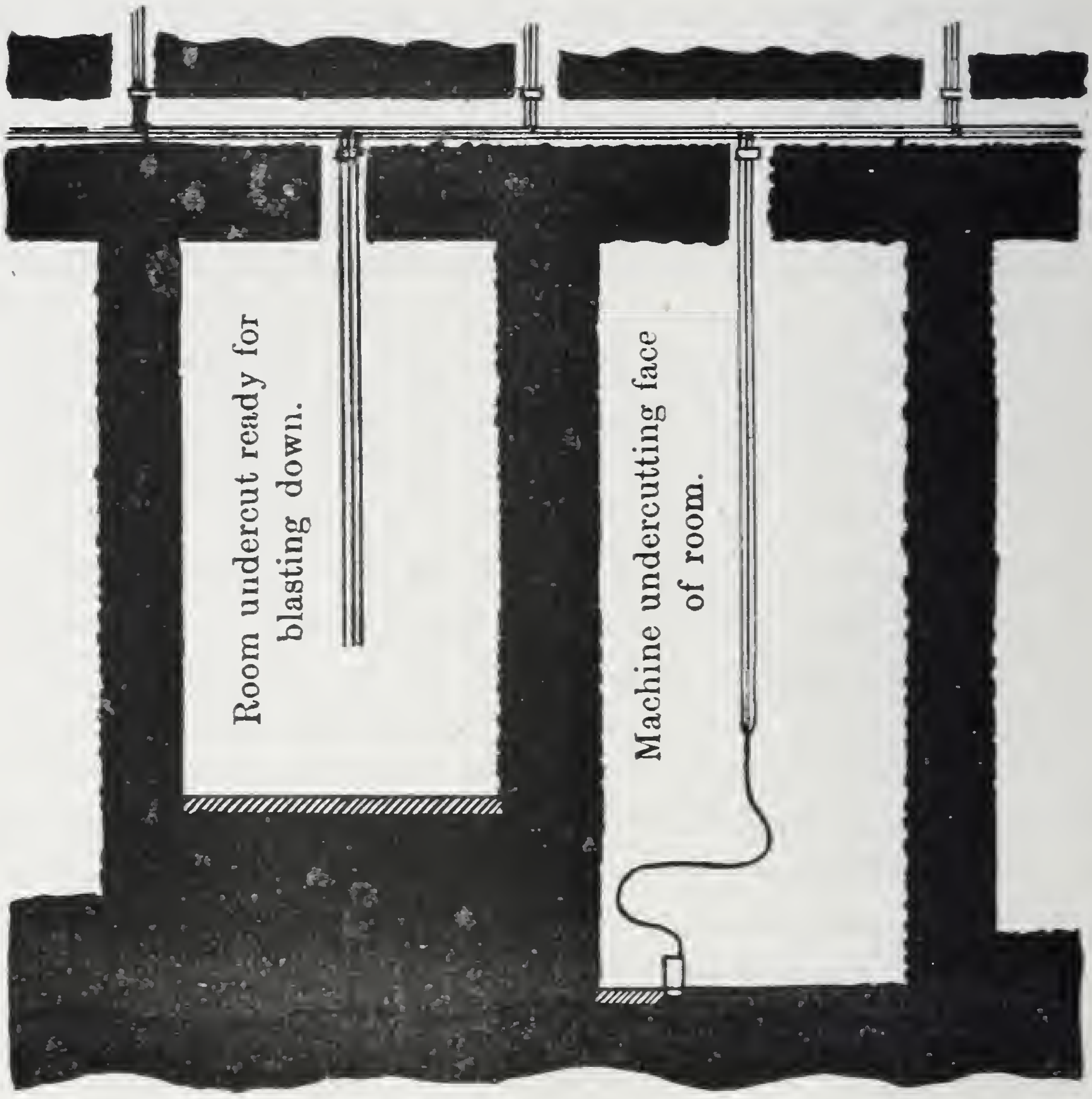


Cut by Pick.



Cut by Machine.

Vertical Sections.



Plan of Rooms and Wiring.

F. Z. SHALLENBERGER: How many machines for the 233 tons?

C. F. SCOTT: Seven.

I. WINN: You say the bits are 3½ inches in diameter. What is the distance from centre to centre?

C. F. SCOTT: It is such that they overlap, cutting out a clean slot.

F. Z. SHALLENBERGER: There might be, I think, a fair question about the advantages being as great as stated. I would like to hear from some of the gentlemen who are practical in mining matters.

A MEMBER: There are some points in the paper that I would like to ask questions about, though I am not a practical miner. There has been no explanation made as to how the rooms are opened in case the machine has to be used in the rooms; whether the machine can be used to make the entry, and whether it can be used to widen out the entrance in the room, in order to get space for operations. If that has to be done by hand, the space occupied by the machine is somewhat more than the length taken. It must have space to work in before it can undercut.

The question to be raised in this connection is whether they have to mine by hand in the usual way until they get room for the machine? and the other question is in regard to the motor, although it is not important. But the Tesla motor is claimed to be very efficient in this connection. No doubt it is, but I would like to know whether the efficiency of the motor, as compared with the direct-current motor, is as high.

F. Z. SHALLENBERGER: Has the direct current been applied to mining?

C. F. SCOTT: The direct-current motor is extensively used. There is a gentleman here to whom I will refer the question regarding the opening of rooms.

The efficiency of the motor may be divided into three heads. One is the actual efficiency in power—the per cent. of the power delivered to the motor which it gives out as mechanical power. Second, efficiency in the simplicity of its working, the liability not to get out of order, and so on; and third, the weight.

In regard to the first, the type that is used has an efficiency of about 80 per cent.; that is, 80 per cent. of the power delivered to the motor is delivered to the belt at the pulley. This efficiency is about the same that would probably be obtained from an ordinary direct-current motor. The direct-current motor often gives a higher figure, which is not surprising, as the theoretical principles underlying its construction are very much simpler. Actual power-efficiency is of little consequence at a coal mine where fuel is cheap. On the second point, I think the figures given in the paper show that this motor is certainly about all that can be desired on that head.

The weight of the motor used is less than is usual with motors of equal power. The weight of this motor, which can deliver from five to six horse-power, is about 360 pounds.

F. Z. SHALLENBERGER: The operation of the Hercules machine does not depend on the kind of motor?

C. F. SCOTT: No, sir. It was operated first by compressed air. It can be operated by any kind of power. We have with us at this meeting a gentleman, Mr. McKaig, who is familiar with the operation of the machine at the mine, and will be glad to answer the question about opening rooms.

T. B. MCKAIG: In regard to the use of the machine for what is called driving entries and turning rooms, I would say that this machine has been used for these purposes, but at present the rooms are being turned by hand at this mine, from the fact that there is no antagonism between the machines and the men, and in the limited space in which the machine has to work there, it would have to be taken out of the entry while the coal was taken down, and the time consumed in that made it just about the even thing between the hand-mining and the machine mining.

At first the rooms were turned and the entries were driven for quite a little time, until the demand grew enough to justify outside help and more of an output than the machines were doing, and then the men were turned in at that work.

The machine is of such a length as will admit of its being turned crossways in the entry. The room would be widened out at an angle, and the machine can be turned around and cut back

square. The rooms can be widened out at will. They can be made of different widths.

F. Z. SHALLENBERGER: What is the greatest length of machine at any time?

T. B. McKAIG: With the bits extended four feet two inches it would be ten feet two inches; but when the bits are withdrawn the extreme length is six feet. That admits of the machine working a space of six feet between the face of the coal and the guards.

F. Z. SHALLENBERGER: If it stood in the entry it would obstruct the entire width?

T. B. McKAIG: Yes, sir; but that would be unobjectionable, as the machine could be made to do the entire work.

F. Z. SHALLENBERGER: Of course, it would not draw ribs?

T. B. McKAIG: Well, it will draw ribs by laying the track in such way right along the rib and then working under it. We have never drawn any.

I. WINN: I would like to ask what the comparison is between the power required by electricity and by compressed air?

C. F. SCOTT: A larger percentage of the power developed by the engine is delivered by electricity than by compressed air; but that depends largely upon the size of the conductors in each case.

A MEMBER: Assuming a case: In case the same width had to be worked by machine as by hand, on account of the weakness of the roof, do you think the economy of work would be as great in narrow rooms as in wide ones?

C. F. SCOTT: The reason for widening the rooms is not because the machines cannot work in narrow rooms, but because there are advantages in wider rooms. Having fewer rooms, you are able to do more cutting with less moving from room to room. These are, however, slight gains compared with the other advantages in using a machine. The ideal way is to do the mining by what is called the long-wall system. That is, there will be no ribs at all, but one long room, which can be gradually advanced, and posts put up behind the machine. All the coal is removed as you advance. The machine can be slid along, from one end of the room to the

other, and there is very little lost time in moving from room to room.

F. Z. Shallenberger: That cannot be done in the Pittsburg vein or else it would have to be done.

I. Winn: How long has the mine been in operation?

C. F. Scott: For nearly two years; it has been running with electricity for about one year and a half.

A Member: I think Mr. Scott's figures in regard to the waste of coal are a little larger than the reality. In the same vein that Mr. McKaig works I know the miners can work with a slot of about 6 inches. The coal is taken out in large lumps, so it is not wasted. Of course the machine mining can be done quicker.

C. F. Scott: The kind of slot would depend on the character of the coal.

F. Z. Shallenberger: How near bottom does the machine work?

C. F. Scott: The machines at one mine work 6 or 8 inches from the bottom, on account of small veins of slate at that point. In other mines, as at Woodville, the cut is down at the bottom of the seam.

F. Z. Shallenberger: The hand-miner preferably works in the lower slate and cuts out the upper one. There are two slates with soft coal. He works in and cuts out the soft coal and also cuts out the good coal above it in order to have room and not be so tight in his working. The slates are separated from the coal. Now, then, the machine, when it works on the bottom, of course, leaves the slates in the coal that is above to be separated. The coal has to be gone over. I suppose the height of the machine can be made to work on the bottom slate?

C. F. Scott: Yes, sir.

A Member: I would like to ask the gentleman with reference to the machine mining, if in blasting the coal is liable to sag and not throw out clear and open as is done by the pick. In the second place, he claims as a point of saving in the wide rooms lessening the number of partitions. Why cannot the miner work as well in the wide rooms as the machine can?

F. Z. Shallenberger: The gentleman answered that by say-

ing that the rooms could not stand up under hand mining as long as machine-mining.

I may say that I have some familiarity with the subject. The miners generally widen out on one side. We will assume that the coal rises in this way (illustrating). The track would run on the lower side of the room, and it would be widened up so that the water could get away and not collect in that corner. These spaces, as shown on the diagram, in the Pittsburg field, are 12 feet for the ribs, 21 feet in the rooms, so that the same kind of iron and turnouts will answer. I believe the spacing is usually about 160 yards now between the cross entries. The 21 feet along the road gives the miner a chance to throw the coal into the wagon from the corner.

A MEMBER: I would like to ask the gentleman to explain the first question, in regard to the blasting of the coal, if it will throw out as well by machine as by hand mining.

T. B. MCKAIG: I will say in regard to this, that the under-cutting is all done before there is any blasting done at all. As my experience with coal mining has been in six months, I cannot say I am a practical coal man; but as I understand it, the miners do not always make the under-cut clear across the face of the room until they can shoot it down. When they put the blast in, it brings all the coal down so that they can get in and lift the lumps out and get the coal down with the pick. I have noticed some miners go in and knock off the face of the slot with their picks in order to get a good fall.

A MEMBER: How many shots do they put in a 34-feet room?

T. B. MCKAIG: That depends upon the manner in which they hold it up, but I think two on the average, with sometimes one in the centre.

F. Z. SHALLENBERGER: I suppose the gentlemen would like to get at the cost as a lump thing.

I. WINN: Do you find any deterioration in the dynamo from dust in the mines?

C. F. SCOTT: There has been no difficulty on that account as yet. The motors are all enclosed.

T. B. MCKAIG: I would like to ask Mr. Scott about the ad-

visability of using the electric light in mines, if it is considered that the current would ignite the gas. That is, in case of the incandescent light, if the globe should be broken, whether that would ignite the gas in the mine if it had accumulated at that point.

C. F. SCOTT: It is pretty hard to predict what may occur under accidental circumstances, but in general, the system of electric lighting can be operated without any danger of igniting the gas while everything runs along normally. There will be almost absolute safety. In the case of an accident, which may not occur at all, or may occur very rarely, in which the conditions may be such that gas could be ignited, there would be danger. I am very confident that the liability of such accident is very much less with the electric light than with any other kind of lighting. With the kind of globes by which this room is lighted there would be no danger of igniting the gas. If the wire be broken, or some accident of that kind occur, occasioning a break in the wire, and if the current be flowing through the wire at the time, then there may be danger, but ordinarily there would be complete safety.

A MEMBER: I think it would be an advantage to have the mines lighted by electricity, as I think it would be safer, as other lights are liable to be put out by the current of air from the fans.

F. Z. SHALLENBERGER: The mining law does not provide for the maximum velocity in the mines in this end of the State, but in the anthracite region it cannot exceed 450 feet per minute. Do the punching machines admit of the application of electric power to them?

C. F. SCOTT: There is one punching machine which is being operated by a motor of this kind, the Michales machine, which is made here in Pittsburg. They have been experimenting with it for something over a year, and it is said by its inventor to now be in very satisfactory shape. A bit is pulled back against a spring; it is then suddenly released by a cam and flies out against the coal. This machine is mounted on two wheels, and is guided by hand up against the coal and rolled around on a platform.

F. Z. SHALLENBERGER: Can a man carry a machine with a motor around with him?

C. F. Scott: He can wheel it around.

F. Z. Shallenberger: How heavy is it?

T. B. McKaig: Eight hundred and fifty pounds is the published weight.

W. L. Scaife: I should like to ask the chair (Mr. Shallenberger) how far your experience agrees with the items of cost as given here?

F. Z. Shallenberger: I think it is correct to assume that machine under-cutting is one-half the whole work of mining. That is the correct assumption in my experience, which has been with compressed air and a little Harrison machine. That machine does very much less work than yours, but it would do the under-cutting of ten men; that is equal to one-half the work of ten men; one-half of all the work done by ten miners, and for attending the men to operate it.

W. L. Scaife: You consider it likely there would be this total saving as shown here by the use of the machine as compared with hand-mining?

F. Z. Shallenberger: Well, that is a matter of proportions a good deal. It takes a pretty large mine to stand mining machinery in my estimation, a mine regularly run, because the outlay for power is a considerable item. The repairs are not very great, but it costs some money to equip a mine, and especially if it is an old one where the mining is some distance from the mouth. It requires also a great deal of watching to see that the conductors are all right, and that they are out of the way when the roof falls. The roof in a mine is soft and needs watching day and night. The machine that requires six feet clear space would probably have to have supports under the roof in this width; that is, there would have to be props moved. You must have miners with the machine, and the machine will not take care of itself, and there must be miners to take care of the roof and the machine. There is a saving in the use of machinery on a large scale, but not on a small scale, because there is a good deal of hand-work to do. There is the drawing of ribs, which is hand-work, and in proper mining the ribs ought to be drawn. In the Pittsburg seam the aim is to begin drawing ribs as soon as the rooms have reached their depth.

Of course, it does not always happen so, but that would be the regular march of operations. The roof is broken purposely in mining, so that there may be relief, and therefore the ribs ought to be drawn. If they are not, the weight is great on account of the long span, and they are bound to crush. You can understand that by the piers being removed the span is wide, and it throws great weight on the supports. This coal has never been successfully mined by the long wall system. I have seen it tried several times. The long wall mining requires a roof that will gradually settle back, so that they can have a long space and no lessening of the roof strength. This coal would break off short, and you would have to set posts close together next to the face of the rib. It breaks off upon them, and then these posts are moved forward to keep a sufficient space for the men to work, and even in such a short reach as that the coal is continually cracking. But it is a great matter to lessen the work one-half of the labor of under-cutting. It is the hardest work a man can do. The deeper under-cut brings down larger coal, compared with the under-cutting by hand, that is the deeper under-cutting by machine, provided it does not use too much powder and blow it to pieces. They had better put three small shots in than two big ones. I think, with these machines, the putting in of the track is something against them, having the track adjusted to the right height. That track is apt to get out of order when the coal is pulled down.

T. B. McKaig: That track does not have to be laid securely. It is laid temporarily and lifted at any height. The machine is right on the track. The rails are not even spiked, and the whole track can easily be moved when the machine requires to be removed from one room to another. It only requires a very few moments to do this. The expense of this is provided for in the daily expense given here, which amounts to but one man for seven machines.

F. Z. Shallenberger: Can you in this mine have 6 feet from the face without posts, if 34 feet long?

T. B. McKaig: They have had, because the roof is supported immediately over the machine; there are really at all times, over the machine, three supports 6 feet apart.

F. Z. Shallenberger: Do you use jacks for the purpose of holding the machine to its work?

T. B. McKaig: They are used to hold the rail down firmly to the floor and hold the machine against the face of the coal.

F. Z. Shallenberger: In some mines here it is not safe to leave more than four feet. I may say that I saw an auger machine some twenty-five years ago. The gears were in pairs, and there was a pinion between them that drove them in pairs. They worked against each other. It was a machine that was driven by hydraulic power. They carried water into the mine under pressure to drive the machine. Of course it was a failure.

J. S. Scully: The greatest trouble we experienced with the machine was to clean out the dust. The first machine we constructed we cleaned the dust out by hand. You would scarcely believe how hard this dust becomes, but now we use what we call a "conveyer," which reaches to the bottom of the hole. It has a rotary motion and a scraping motion at the same time, and does the work very well.

On the subject of expense, of course the machinery is very expensive, and it is expensive to equip a mine. A mine ought to be run on a pretty extensive scale to pay, but still the machine can be employed in a small mine. I have not the exact figures at hand, but we had a machine in a small mine and the work was very satisfactory to us. And, besides, there was a great deal of dead work to be done that would not be needed in a new mine. Of course at that time we were paying men a little less than we are paying now. They are paying now ten cents for undercutting and forty cents for shooting down and loading.

I would answer the question about the throwing out of the coal by saying that I have frequently seen one shot do the whole work, bringing the whole face of the coal for a long undercut. That does not always occur, however. It is better to put in a shot in each corner. As to the size of the rooms, there are some 21, some 24, and some 36 feet, working successfully. I do not know what they are working at the mine now. I understand there are a number of small rooms being worked 20 odd feet.

As to the handling of the machine, of course everything was

new at first, but now the miners are quite skilful, and they are greatly pleased with it.

Mr. Scully then related an incident of a miner who had called on him only the day before who spoke very highly of the working of the machine.

C. F. Scott: Since the data for the paper was given to the Society the machines have been running, and I was favored to-day with the results which have been obtained lately. The figures cover the first twenty-nine days of consecutive running during this year, in January and February. During most of that time three machines were running, though a number of days only two were working, because the orders for coal were small.

2465 tons of coal were cut, an average of $28\frac{1}{3}$ tons per day per machine. Taking the actual hours during which the machines were running, the average is $3\frac{7}{10}$ cuts per hour, or for ten hours 37 cuts, or 37 tons. The machines worked less than ten hours per day, because more coal was not wanted. The estimate given in the paper is 33 tons per day, so that the machines have been doing, during the last two months, a greater amount of work than estimated in the paper.

The cost for repairs during that time was a trifle less than that given in the paper, $2\frac{1}{8}$ cents per ton. For these twenty-nine days it was 2 cents per ton. In the figures given in the paper those of the cost of turnouts and driving of entries may be excessive, although the figures given in the report are those furnished by a mining engineer. I called his attention to the fact, but he still held they were right. But even if those items of saving were to be thrown out entirely, and nothing at all were counted for the estimated saving on turnouts and driving of entries, that would make a very small difference in the final estimate.

The application of electricity in mines is not confined to the mining machine. There are various other uses, such as running hoists, fans, etc. Indeed, a large fan and a centrifugal pump at the present mine are run by motors.

Light has also been mentioned. With a better light and no smoke a better class of labor can be employed. Mechanics can go in to take care of the machine. There is less danger from gas.

Besides the economic advantage of electric haulage, the mule drivers, a most troublesome class of citizens, are dispensed with, and the mule, also, will have to retire.

This application of machinery and electricity in mines is raising the trade of mining above that of slavery, and giving it a dignity. It cheapens one of the most important commodities of our ordinary domestic life and of our commercial and manufacturing industries. If the profits which have been figured, I hope not too liberally, are forthcoming they may secure for a time large profits to the mining operators, but it is hoped that later they will lessen the cost of coal, and be of general benefit in lessening the price of fuel, thus cheapening the cost of power; and power, you know, is the vital element in every branch of our present civilized and manufacturing life.

The meeting closed at 10 P.M., some of those present having to walk through the river, which was fast rising, to reach dry footing.

J. H. Harlow,
Secretary.

March 17th, 1891.

Society met in the parlors of the Thaw Mansion at 8 P.M., with thirty members present.

The minutes of the last meeting were read by the Secretary and approved. There was no special business transacted.

A minority report on Roads and Road Laws was read by Mr. Arthur Kirk, and after reading was discussed by the following gentlemen: Messrs. Hunt, Payne, Swensson, Johnson and others.

Adjourned.

J. H. Harlow,
Secretary.

April 21st, 1891.

Society met in the parlors of the Thaw Mansion at 8 P.M., with fifty-six members present.

The minutes of the last meeting were read by the Secretary and

approved. Mr. A. Dempster read a circular from E. L. Corthell and others in relation to the monument for James B. Eads, member Am. Soc. C. E., and it was moved that the Secretary have circulars printed and distributed among the members of the Society.

Mr. Daniel Steinmetz described the workings of the Fales Grate, and answered many questions from the members in relation to same.

Mr. John A. Brashear called the attention of the Society to two samples of steel castings, one made by the Chester Steel Casting Company, of Chester, Pa., and the other by the Reliance Company, of Pittsburg. Mr. Brashear said: "The reason I brought these two specimens is on account of what Prof. Langley read in his paper about the steel castings made in Sweden.

"You will remember I said in the discussion that we had trouble in getting steel castings. The best results had been obtained from those received from the Chester Steel Casting Company. After that meeting I met a gentleman, who is a member of this Society, who said it was a shame we had to go to Chester for castings, and asked me to give him a chance to make some for us. We sent a pattern to him, the next time we had an order, and for fear it would be bad, also sent a pattern to Chester. The castings received from the Reliance Company are more easy to turn than the Chester. They are very nearly homogeneous. You will notice that the casting is a very perfect piece of work. In the Chester casting you will notice there are soft spots that make the casting very difficult to finish, and in the inside there are some very hard spots that takes the corner off any tool we have."

The President,Mr. Roberts, called upon Mr. Phineas Barnes to read a paper on Co-operation in Machine Design. This was discussed by the following gentlemen: Messrs. Hyde, Roberts and others.

CO-OPERATION IN MACHINE DESIGN.

BY PHINEAS BARNES.

History has recorded, for those who will take the trouble to read, and ample daily experience has fully certified this record, that all prudent men should take heed and beware of "the man of

one book." If it be not taxing too heavily the exact significance of this precept, an inquiry may perhaps be pertinently made as to why a guard should not be set, although in a reverse sense, against the man of one book (or of one idea) in the art of machine design, this term being taken in its large or true sense, and including the conception of the plan, the execution of the work as an item of manufacture, and also, often the consideration of all others, the placing of the finished machine in operation in the factory or the field.

This same unerring historian, the record of actual experience, will set before the reader, if duly consulted, sundry illustrations, perhaps many within a moderate range of vision, of imperfect successes, not to say failures, either noteworthy, lamentable, or even ridiculous,—sometimes one, sometimes all,—which can be traced directly, often upon the instant, to the control held and insisted upon by the man of one idea. This unit man may have been a host in himself, perhaps a dozen, a score, even a thousand, in his intention in whatever subdivision of the finished work he may have been tried; but from a single unit, absolutely complete though it may be, an active hundred cannot be made, still less a thousand, unless the needful ciphers be added and held firmly, those precious nothings which count so effectively for value if only they are rightly placed.

The machine designer who has not been taught, in his earlier training, to confer with those upon whom he must rely for the execution of his designs in iron, steel or brass; or the man who cannot thus rely, by reason of distance which cannot be bridged, upon the judgment of him who must command on the field in the industrial battle, for which the machine in question may be as a piece of heavy artillery, a light mountain howitzer, or even a cartridge-box, this man, who cannot, or will not, see the end of his work from the beginning, may certainly be named as of one idea—a useful, wholesome idea, but one only when, for the moment under consideration, there should be three, closely linked and, indeed, inseparable.

The current record of engineering practice in nearly every important manufacturing centre will be found upon examination to

contain some examples, perhaps many, of this form of imperfect vision of the end of a scheme from the beginning. Since the use of this term machine design, in this brief note, is understood to include, as it always should include, the adaptation of the machine to the specific detail which it must accomplish, and also the placing of the machine rightly upon its foundation and in harmony with its surroundings, the charge must necessarily be laid upon some one of furnishing, or at least of combining these views, perhaps discordant, with such links or joinings together as shall at once justify the technical methods and the financial outlay.

The constructive world has seen instances enough of work undertaken in the older way, the design, and perhaps the finished plans, having been wrought out by one mind, the building of the machinery and kindred fixtures by a second (and independent) master, and the whole placed and put in operation by a third manager. Three such men have sometimes been found, each emphatic in himself, who can thus plan and place important things, each part dropping accurately into its own place, but the chance is rather that these effective helpers, unless they are men of more than "one book," or idea, will not see the ending of their work, its vital point, from their first connection with it, or, indeed, from any intermediate point during its progress.

By way of illustration it may be suggested that the man who would design a heavy engine of enduring stability, might be expected to take pains to find out, if he did not already know, that the static friction of his machine upon its foundation, upon which alone its stability usually depends, can be assured only by broad contact-surfaces, and also, what is equally important, that this static friction depends for its permanence upon the uniform distribution over this broad surface of the pressure due to the tension of the foundation bolts placed at or near the centre of these surfaces, and not at or outside of their edges.

Why should not a maker of such things as heavy steel castings make them of such quality or texture as should certainly insure the ductility or toughness called for in the service they must render, and actually shown in samples referred to, when he had been given absolutely his own choice of time, materials, method and

price, if he had only realized the ending of his work as it must eventually appear.

Why, again, should a man, a foreman for many years in charge of building heavy pumps, keep so closely to his work at home that he had never seen, or had been kept from seeing, the outcome of his labor and painstaking, the actual working of the machinery itself under its normal conditions, often trying, sometimes critical.

Why should a manager on similar work stick so closely to his last, shoemaker fashion, that it had never occurred to him that a heavy stud-bolt—that *bête-noir* of the men in charge of repairs—should be shunned if not like a pestilence, yet certainly as a possible and sometimes inevitable cause of delay and disaster.

Why should an indulgence in the present leaning toward the use of hydraulic machinery lead a designer to suggest the use of a heavy shear at a cost probably three times greater than would be due to the use of a geared shear corresponding to the capacity of other parts of the mill-apparatus, of a capacity in speed of from one-third to one-fifth, and with a probable loss of energy by leakage and friction three times greater than the power shear thus referred to—how, in fact, could this be done if the designer had been, in the sense of this note, a man of more than "one book."

Why should an engineering instructor ignore, as some certainly do, a critical study, with his pupils, of the pertinent language of the wear and tear of construction material, a language which, if not formulated into a vocabulary or classified in exact terms in a lexicon, is yet written, like the story of the ages, out in the rocks; upon countless details of worn and broken machinery which can be had, nearly for the asking, from the contents of any scrap pile. This is the language, too often appealing in strong terms for a correct interpretation, of the life led, or at any rate illustrated, by those horny-handed sons of toil, the repair-hands of the ordinary mill or factory. These are often men of might, whose early education may have been neglected, it is true, but who, nevertheless, can often exhibit a skill which is simply admirable in the use of those homely tools, a monkey-wrench, a crowbar, and a sledgehammer. It is certainly worthy of an honest desire, that those whom it may concern should themselves learn and teach this lan-

guage, if any committed to their care are to see the end, before they themselves reach it, from the beginning, for through its mute indications may be discerned the gathering of those conditions which only tend toward disappointment, discouragement, and eventually bring destruction itself.

Discussion.

A Member: I am reminded strongly by one thing mentioned by Mr. Barnes of an incident that happened under my observation with regard to the inventor of the Buckeye engine, of which probably some of you have heard, Mr. J. W. Thompson. He was one of those designers of machinery who, kept very close at home, had very little opportunity to see his design in operation. At one time he was working on an engine of his design, the largest one they had ever built under his patents, and there was considerable trouble found with the operation of the valve gear. It did not seem strong enough for the work it had to perform. I had some correspondence with him in regard to it. Among other things I said I would like to know if he was sure the main shaft and its bearing on the engine was strong enough for the work it had to do.

His characteristic reply was: "How can I be sure of such things when I have never had an opportunity to go and see them," and I think it is often due to inventors and designers that they be given greater opportunities to see their designs in operation, especially new inventions. In this case it appears that no such opportunity has been given. Perhaps he did not make any strong effort and make his opportunities, but the fact remains that he did not have them.

Mr. Hyde: I would rather like to take exception to Mr. Barnes' rather sweeping condemnation of the hydraulic shear. He says, in the first place, that the cost would be three times that of the gear shear, with three times the loss from leakage and friction, and would only work at one-fifth the speed. Now, there are shears in Pittsburg, to day, in operation, as well as in other centres of the steel industry that have been built for at least the cost, and in some cases I know of, for about one-half the cost of the gear shear to do similar work. They can be built to do the same work,

and although the speed may not be quite equal to the speed of the gear shear, it is still fast enough to do the ordinary work of the blooming mill. I think he carries his opposition to hydraulics too far, especially in the case of the hydraulic shear, which has shown that it is a very useful tool about steel works, and is not so liable to get out of repair, so far as my experience goes, as the gear shear.

Mr. Roberts: I am glad to hear that hydraulic machinery is not so bad in that tool. I favor it myself wherever it can be applied. I think Mr. Barnes overlooks the fact that it is often difficult to see the end from the beginning in the desire to accomplish some specific object. I think the best inventions are those which arise from necessity. They come up often accidentally. You know the story of the lazy boy who invented the cam shaft by hitching it on to the driving wheel to save himself labor. I do not think we can foresee them, for we cannot foresee what we do not want. Our growth in every department seems to be slow but progressive. "One step enough for me," as Cardinal Newman says in his beautiful hymn.

A Member: A thing that struck me in Mr. Barnes' paper—it may be because of the business I am engaged in—is where the designer overlooks those who are to carry out his design, as, for instance, the moulder and the machinist. He forgets, sometimes, the difficulty that the moulder has to encounter; he forgets the quality of the material, in the thicknesses that come together, in the shape, often doubling the cost even in the casting. In the designing of the shape and form when it comes into the machine shop, the cost is often increased, whereas, consulting with the one who has to carry out his design would very often materially decrease the cost.

The following new members were elected: Messrs. J. J. Thoresen, Samuel Foster, C. B. Connelly and J. Atwood.

Adjourned.

J. H. Harlow,
Secretary.

May 19th, 1891.

Society met in the parlors of the Thaw Mansion at 8 P.M. with thirty-two members present.

President Roberts in the chair.

The minutes of the last meeting were read by the Secretary and approved.

The Secretary called the attention of the Society to the death of Edward Armstrong late Chief of Public Works, Allegheny City. The chairman directed that a committee be appointed to prepare a memorial.

T. P. Roberts, the President, presented the Society with a set of ten maps, showing the location of the Lake Erie and Ohio River Ship Canal. The largest one is a general map, showing the whole of the western part of the State, through which it is proposed to build the canal. The others are smaller, showing the canal, locks, and water supply at various points along the route.

Mr. Thos. J. S. Sawyer was elected a member.

The paper of the evening was read by Mr. H. B. Chess, as advocated by the Atkinson Company of Boston, Mass., on

SLOW COMBUSTION CONSTRUCTION OF BUILDINGS.

In the United States nature has been lavish in the matter of timber supply, and our injudicious, not to say thoughtless, use of it has been largely responsible for the enormous annual loss of $125,000,000. In one year it reached $142,000,000, and at the rate being maintained during the current year, with $50,000,000 loss reported in the first five months, we bid fair to keep up the record. Coming home to our own community, Fire Marshal McFadden of Pittsburg reports the gross loss of the year ending March 23, 1891, at $1,283,000, of which $994,691 were paid by insurance companies, or within a few thousand dollars of a round million. These rough figures of the national and municipal loss do not cover the cost of the fire department and its equipment and maintenance, of private fire apparatus, water consumption, etc.

In Pittsburg, for instance, we find the outlay of our fire department for the year ending January 1, 1891, to have been $245,495. This expenditure added to the gross loss given makes the municipality's annual contribution to this moloch just about $1,500,000!

Thoughtful minds in America have developed systems of construction and invented safeguards and preventives. Improved structural material and their adjustment and arrangement, innumerable devices for extinguishing fires automatically, and otherwise improved fire extinguishment services, sprinkler service, etc., have been developed. While they have seemingly been brought to the highest pitch of perfection, the fact remains that losses by fire continue at an enormous rate. It is not generally appreciated that the loss of the nation by fire is about one-third of the whole

FIG. 1.

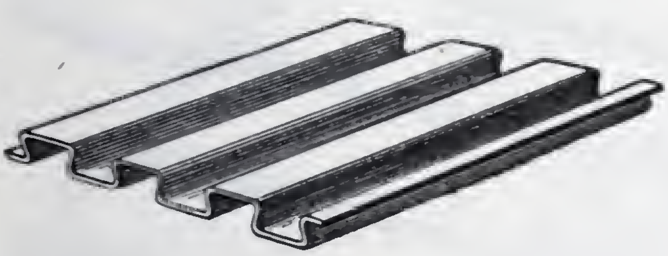
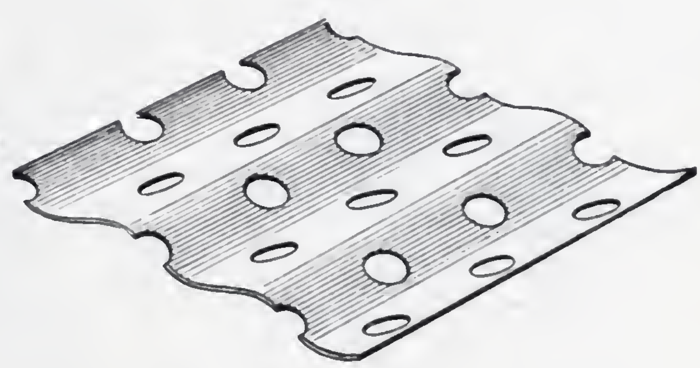


FIG. 2.



return from our wheat crop, so laboriously garnered, or as nearly as may be estimated close to the value of one year's production of pig metal. Innumerable laws, ordinances and regulations prevail in every considerable city, to which are added the specifications and requirements of that very vigilant army, the fire underwriters. All are wholesome and praiseworthy as laid down, but somehow are lamentably short in practice. In thrifty New England a scheme of mutual insurance has been developed, and so successfully maintained over a long period as to be a pronounced success in every way. It does not pay out of an accumulated fund to recoup losses of a brother who possibly built so as to have deliberately invited the calamity incurred, but its main business is to have the brother so build that so far as human foresight can provide he cannot easily burn down honestly. After these requirements are complied with, he is admitted into a partnership

which makes up to him a loss if it comes. The class of buildings insured is mainly textile factories and storehouses. These have undergone such a transformation in their structure, that the term "slow combustion construction" has been applied to the system. This is most admirably described by that versatile gentleman, exponent and president of the Mutual New England Company, Edward Atkinson of Boston, in a popular article in the *Century* of February, 1889. The term itself seems clumsy, but for its honesty and expressiveness, it has come to stay. Mr. Atkinson—whose statistical statements none will gainsay, however much we Pennsylvanians differ with him in some features of national economics—asserts, and proves by the record, that by sedulous observance of their regulations and by their constant supervision, the fire losses

FIG. 3.

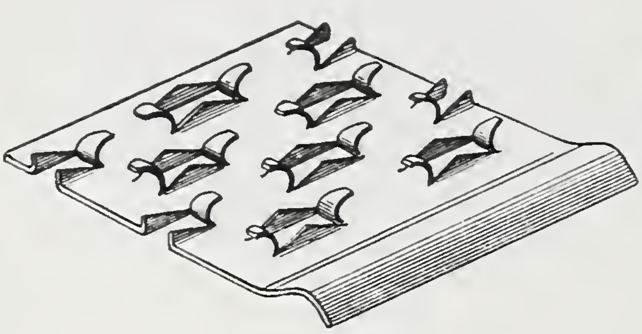
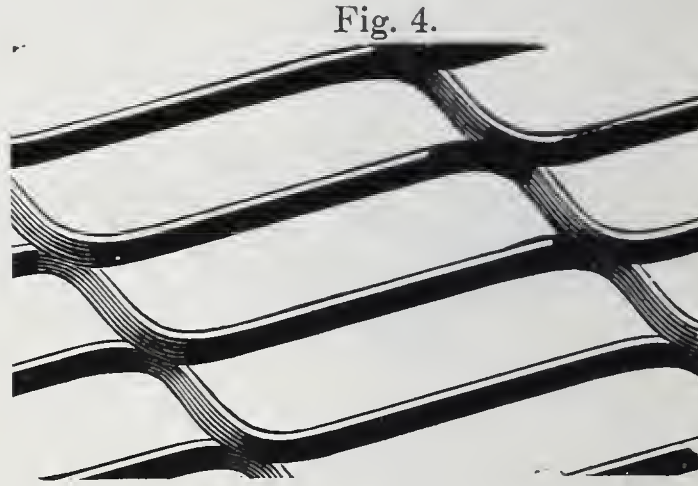


Fig. 4.



have been reduced much below general high-grade risks of the country, even in that department of textile factories known as "picker."

In Japan there has been in use from time immemorial a domestic institution, singularly unique, in the shape of a fire-proof structure, used by all classes as a safe place for their valuables on the occasion of frequent and destructive conflagrations. The walls are built upon a vertical foundation, or screen, of bamboo and netting, by successive additions of small clay masses, the construction frequently occupying two years. Doors and windows are made of the same materials as the walls and roof, and they have stepped edges like our own safes. At the approach of fire valuables are hastily gathered together into the Kura. The crevices of the doors and windows are quickly closed up with soft

wet clay, so that the structures are built not to add in any degree to the conflagration, but to absolutely resist its attack.

We cannot build high and many-storied Kura, but we can modestly take the suggestion to meet fire with earthy matter, and with that alone. It is admitted that ordinary wood lathing is

FIG. 5.

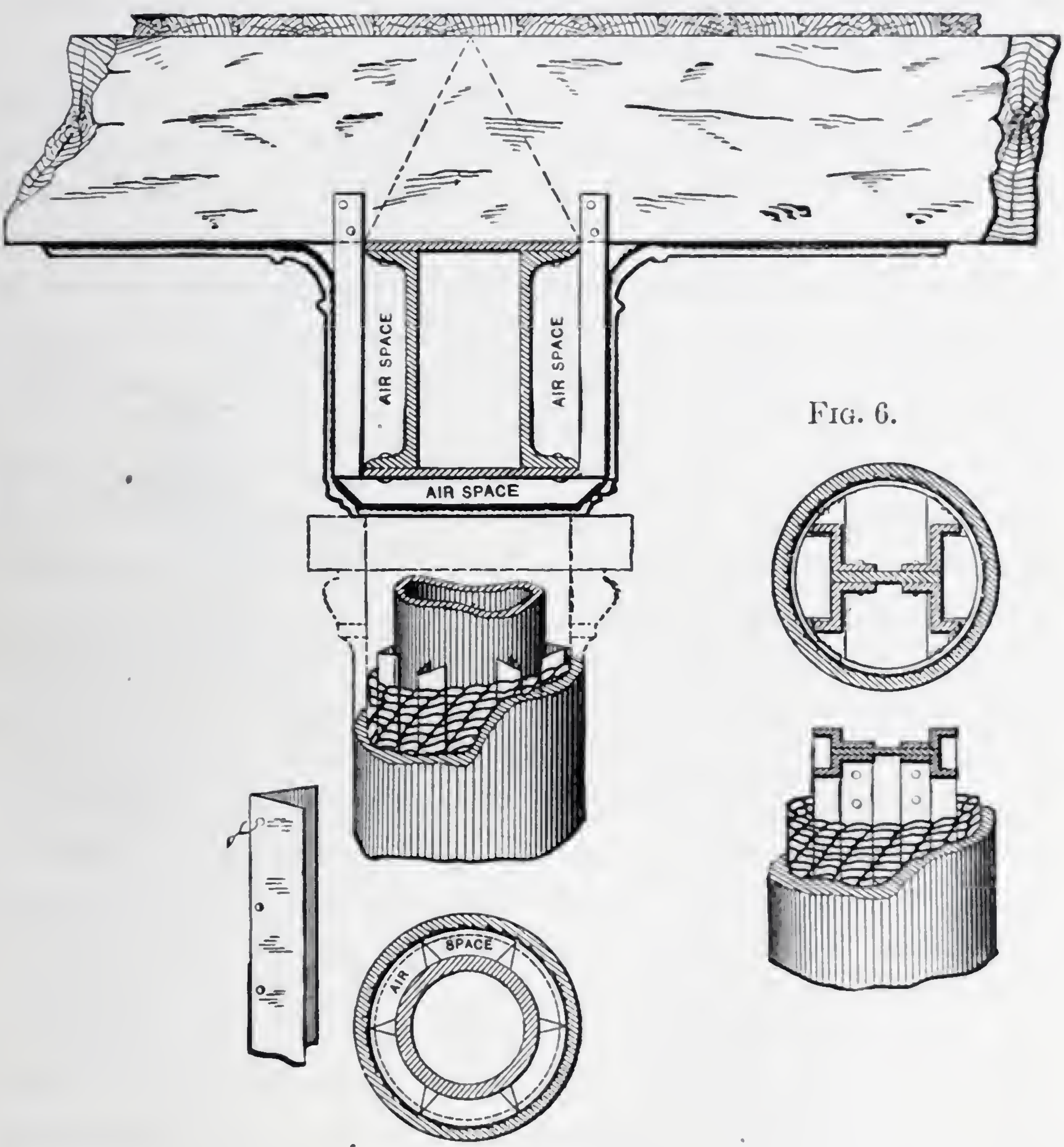


FIG. 6.

entirely deficient in supporting that excellent flame-resistant, common mortar. It supports plaster poorly enough under ordinary circumstances, but it utterly fails in opposing fire attack, and affords a most admirable kindling of thoroughly dry light wood to the rapid widening of the flame. When it is considered that the

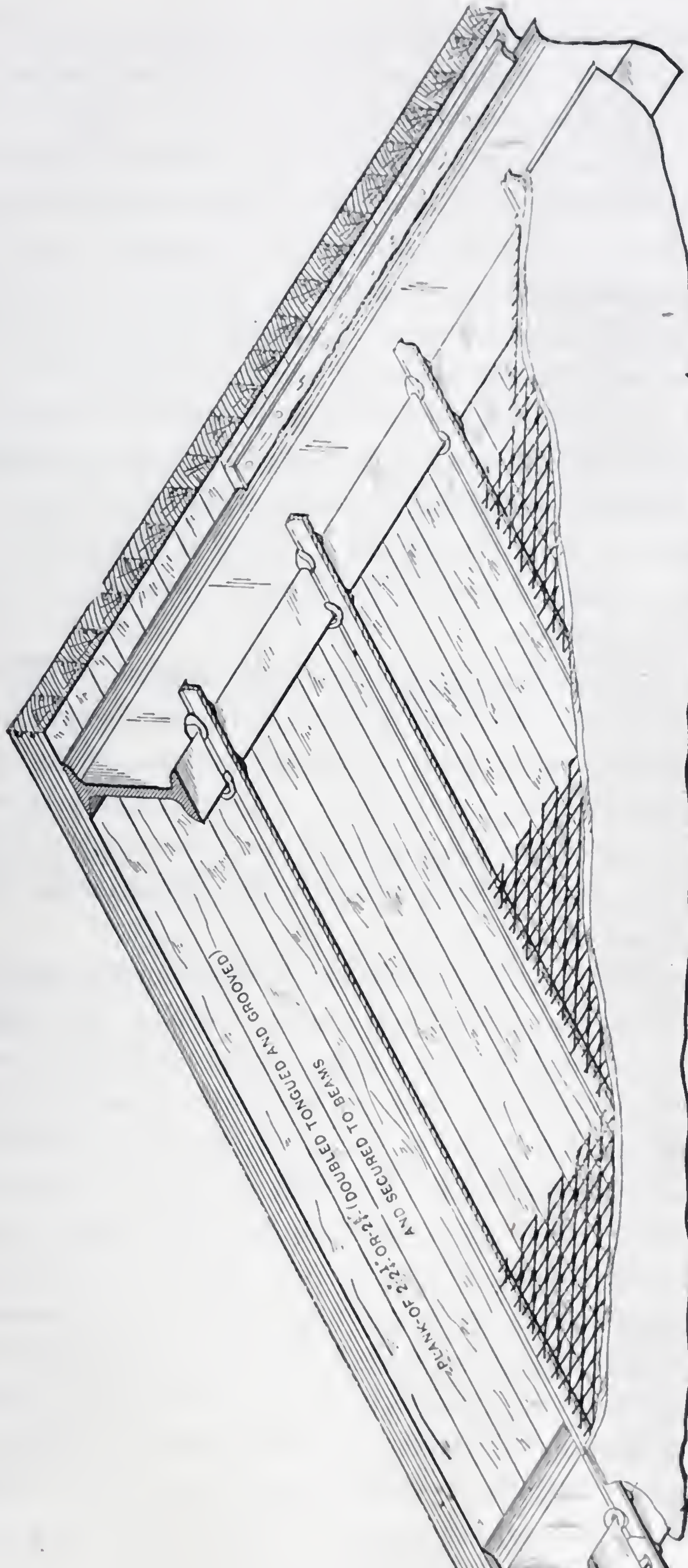
plastering and chimneys are the only fire-resisting material entering into a very large share of America's structures to-day, it is not to be wondered at that such an amount of treasure is destroyed. Even in our brick houses outside of the walls the same condition exists. Floor, partitions, ceiling, etc., all add to the fire. The plaster is well enough, but the manner in which it is attached seems entirely wrong, because it does not hold, and because it contributes itself to the conflagration.

Allow me to present some elements and features of a fire-resisting nature, hardly new in all details, but certainly not old, and generally well known collectively. And while quite in line with the economic aim and purpose of Mr. Atkinson's company, embodying the same effective underlying principle made use of in the Japanese structure noted, these features are capable of application in our everyday building of all grades, and without limitation of the latter to kind or purpose.

As a foundation for plastic material, metallic lathing, in its various forms has now had extended use, and has proved itself of great economical and structural merit. When of good form it holds its coating unflinchingly, filling the dual function of protecting itself and the structure it sustains. Even when through faulty form and quality it fails in holding its coating, it is at least incombustible, and it does not add treacherously to the burning. A good metallic lathing should be capable of easy application, should be properly rigid to yield good workmanlike result of coating and surface, and should readily permit moulding into any form called for by the structural requirements, and finally it should yield all the keying possible. It should have practically an equivalent co-efficient of expansion and contraction with its plastic load through extreme ranges of temperature, and not fling it off by buckling. Three general types have been designed to meet these requirements—namely, netting of various gauges of wire, perforated sheets and expanded metal.

The wire was probably first used in the form of plain netting, woven with square interstices of about $\frac{3}{8}$ inch. To produce it at a reasonable cheapness the gauge was gradually reduced, and to make up for its consequent lack of rigidity, stiffening members

FIG. 7.



Composite Floor.

are introduced transversely in the web at short intervals. These members are either of light sheet-iron made prismoidal form or V-shape, or they may be of, say, $\frac{1}{4}$-inch rods. Again, corrugations or trusses have been struck up across the webs both to stiffen and to yield "furring," *i.e.*, maintain a distance out from joist or studding. Again, plain netting, of say 18 gauge, is galvanized, thus soldering the wire at intersections, giving a most excellent lathing, but its greatly enhanced cost forbids its general adoption, and I may remark that it is not generally considered by experts that the zinc coating is any improvement other than that the incidental soldering of the wires gives a rigid structural quality.

Before referring to perforated metal lathing it may be proper to call attention to a dovetailed corrugated sheet, Fig. 1, the crumples or corrugations of which furnish dovetailed recesses for the reception of mortar.

In perforated sheets proper one system consists of light corrugated iron about 4 inches wide, Fig. 2, with staggered perforations, through which tongues of plaster project, giving a certain amount of key. This, while it is a great improvement on the rigid, unperforated dovetailed form last described, and is of a yielding nature transversely, is dangerously the reverse in a longitudinal direction.

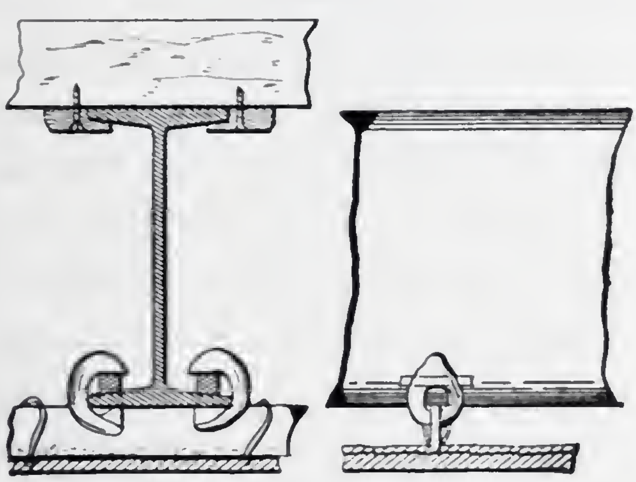
Another form is that of sheets 15 inches wide, perforated at close intervals with a pyramidal punch, so that the ragged burr made forms at each hole four ragged claws to clutch the coating, while tongues of the latter may go through to assist (Fig. 3).

These examples are typical and cover the more important forms of perforated sheet systems. We then come to a cross between wire netting and the systems just alluded to, embodying probably the valuable qualities of both types without the drawbacks of either, shown in Fig. 4. It is an adaptation of expanded metal, and is known as expanded metal lathing. It will be observed that it is tight, self-bound and so full of interstices as to give keying throughout all of its surface. Being made of steel it is strong and tough and may be moulded like sheet lead. Indeed, the moulding into corrugated or curved forms only makes a more rigid structure. Its peculiar form creates a space back of it, thus

providing for "furring" so as to clinch the mortar. It cannot be nailed so close as to prevent this. A simple experiment proves how unflinchingly it holds the fire armor for wood. The lathing has been simply nailed to the surface of a plain hemlock board and common mortar applied to the whole. Dropping it upon the floor, the mortar is not detached by the shock. The metal makes a dainty series of slight tied girders whose edges stand perpendicular to the face of the mortar, and under great fire stress are so disposed as to prevent the mischievous stripping. In other words, the metal fabric remains neutral in its plastic bed.

An architect who had prepared this sample as a study of stippled surface for exterior use, tested its fire-proof quality by keep-

FIG. 8.



Sections of Floor.

ing it four or five hours over and in a glowing gas fire in his grate and cooling it under a stream of water, so as to simulate the conditions of actual fire. He repeated this double operation to his entire satisfaction, the sample coming out of the ordeal in an unchanged condition structurally, as is evident on examination. The naked lathing at the edge of the plate was heavily oxidized.

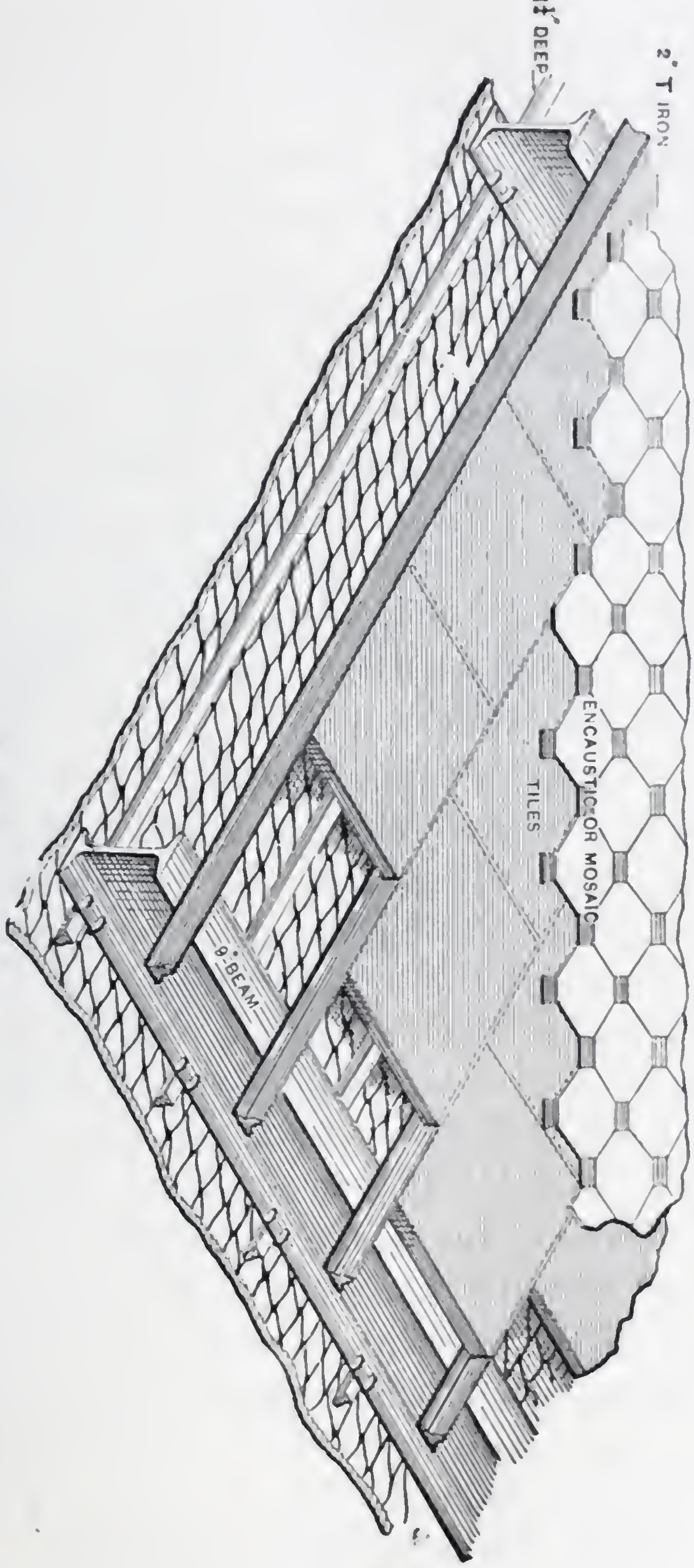
A small structure was built of fire-brick, with a clear height of 5 feet, and was roofed with common 2 × 12-inch hemlock joists. Just below the ceiling small openings were provided for the egress of flame at the sides and larger arched openings at both ends low down, for air supply. The ceiling was made of common plaster applied to expanded metal lathing, simply nailed to the bottom of the joists, without furring or distance. The joists

were covered with old sheet-iron simply laid on. A fire was started and vigorously maintained with old oil barrels for over an hour, when a prominent insurance party present called out "Enough." Although the fire-resisting coating was only common plaster, it was unflinchingly held. It was found that while the superficial skin-coat had flaked off here and there, its body was intact. A piece of pine studding, 4 × 4 inches, wrapped with expanded metal lathing without air space and plastered in the usual manner, was laid across from wall to wall, a space of 6 feet, where it remained in the thick of the fire during the entire experiment. When it is remembered that nowhere was its surface more than 2 inches from the centre of the section, it is a remarkable fact that quite a core of unburnt wood was left to sustain the beam, as it did, through the test. Through the intervention of the inclosing jacket of plaster the charcoal of its exterior portion had not been allowed to be consumed to ash or to fall away. Similar successful tests, it is but just to say, have been made in quite a number of cities by makers of wire lathing, all pointing to the fact that there is a well-defined systematic method of using a universal material of the greatest value in such a manner that we shall not readily burn down; in fact, may build any form of structure "slow combustion" and at reasonable outlay.

Let me say one word in regard to the Denver competitive tests which have deservedly attracted our attention because they were manifestly fair so far as they dealt with an important detail, and would seem to be authoritative and conclusive that far, but you will remember the fire-walls of the firing tests were placed properly enough 2 inches in from the lower limb of the I-beams. They furnished not only the needed protection to the metal member so essentially an integral part of all such systems, but they also supported squarely the arches at their spring. Both, clearly, were conditions so remote from practice as to be remarked upon by the arbitrating experts. Manifestly and fairly, the whole constituted a decidedly negative test, not at all complimentary to the system as a whole. I beg also to recall that the experts' report on the final condition of the material entering into the arches gave un-

bounded praise to the cement mortar used. In all the tests it was of all the materials the only one apparently unchanged. With

Fig. 9.



Incombustible Floor.

the aid of illustrations let me present some applications of these fire-resisting, metallic-bound coverings in ordinary constructions.

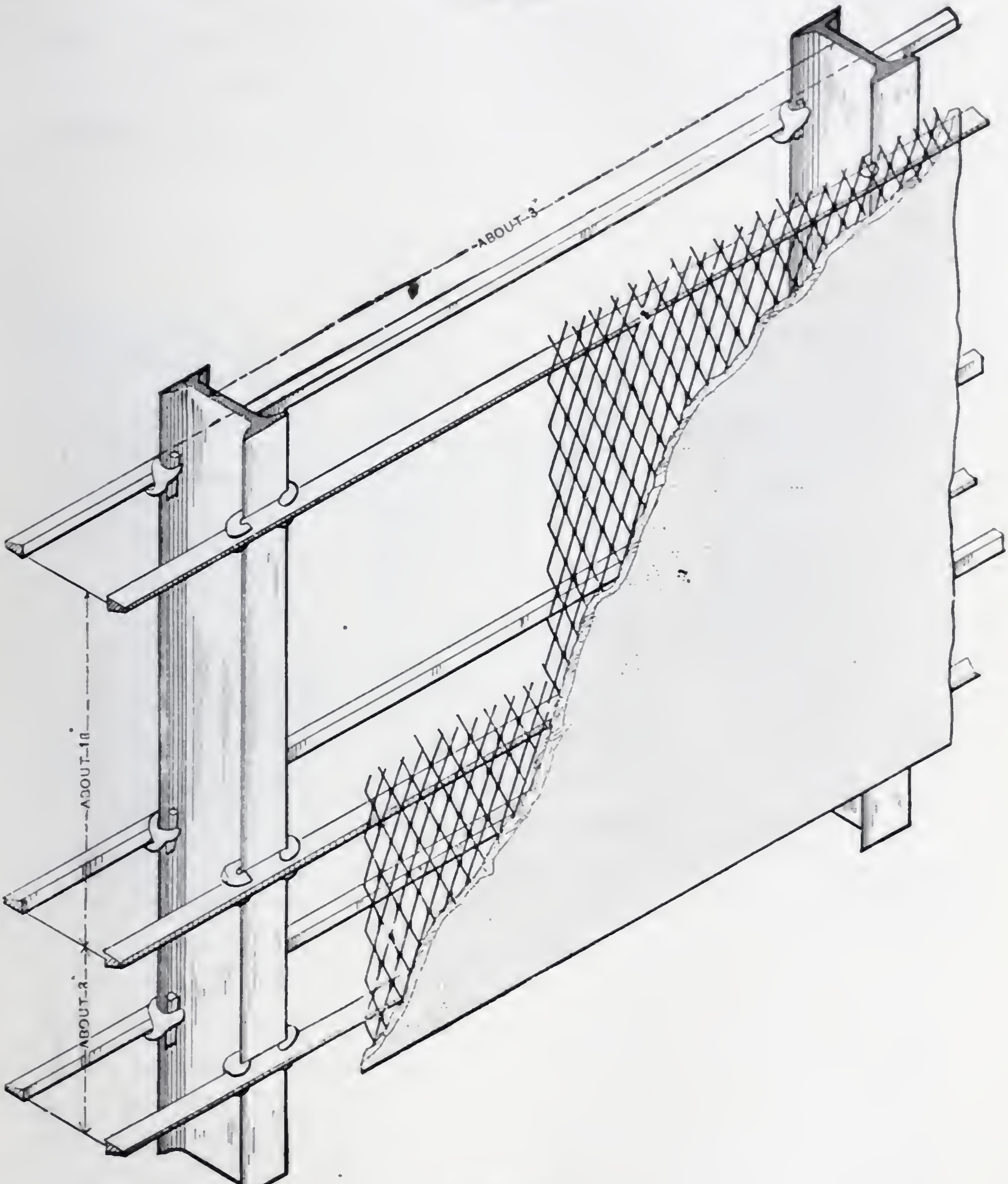
Fig. 5 shows a method of protecting a common iron box girder, wooden joists and cast-iron column. Light loops or straps are nailed to the joist. Expanded lathing, starting from the joist, bent into easy curves at the girder, is wired on to the strips, giving unbroken connection between ceiling and girder covering. It is plastered and ornamented in the usual manner. The column has placed about it, at regular intervals, strips of light sheet-iron bent into **V**-form, and slightly held until an expanded metal jacket is securely wound around it. A plaster and cement coating is then applied, and swept on this foundation. The whole protecting coat is of a monolithic character. Of itself, structurally, this strong cylinder is of no mean added value. Large valuable air spaces are provided in both girder and column.

Fig. 6 indicates the manner of fire-proofing the **Z**-bar wrought-iron column. The furring in this case takes the form of light loops sprung into place, giving approximately a circular shape for the jacket of lathing as before, with the essential air spaces. Figs. 10 and 11 show an incombustible partition capable of being a supporting one. Studding of I-beams are properly spaced, say approximately in 3-foot centreings, and light iron furrings $\frac{3}{4}$-inch in depth are clamped by keys to the former in a horizontal direction and on a spacing of 16 inches. This detail may be varied to meet the exigencies of the situation. Thus, at the top of the wainscoting it may be closer, as shown. No special care need be taken in spacing either the studding or the furring; no drilling or tapping is done; no bolts or screws are used. The section of studding may be varied. The oblong mesh in expanded metal permits easy wiring at any location, and plaster is applied in the usual manner. We thus have supporting vertical members of iron, tied and braced by the cross-furring, reinforced by the steel lathing foundation, and over all plates of good mortar, making a partition of undoubtedly great sustaining power in every way and not fragmentary in its make-up.

A cheaper but equally incombustible partition, of a fire-screen nature, is made by erecting studding of plain 2-inch $\times$ $\frac{1}{4}$-inch iron. These have feet turned on them top and bottom, perforated for nailing into place. Lathing is wired to both sides, and this plas-

tered in the usual manner. What with the tie-bracing of the lathing and the projection back of mortar at and about the edges

FIG. 10.



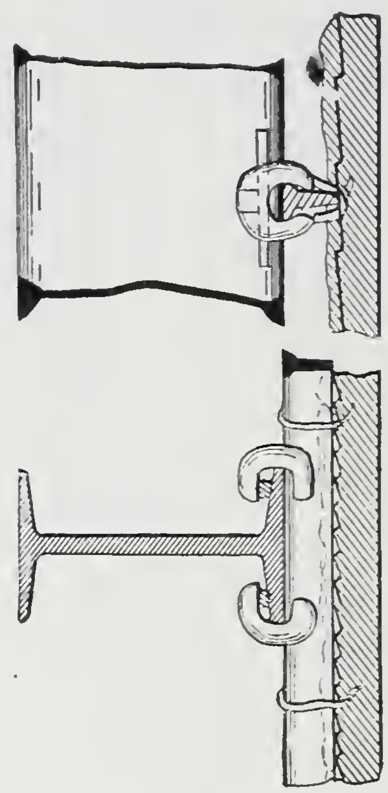
Partition.

of the studding, these are so thoroughly bridged that a fairly stable structure results.

Again, let me present a floor which, when covered with wood,

is called composite. I-beams of proper section and depth, Fig. 7, span the building at centreings of 6 to 7 feet, and with no particular care as to spacing. On these the Atkinson or factory floor is laid. Instead of the one spline, we propose double tongueing and grooving. Scantling 3 × 4 inches, easily obtainable anywhere, will give us $2\frac{3}{4}$ by about $3\frac{1}{2}$-inch face flooring. This is laid and clamped as indicated, while underneath is clamped transversely, just as in the case of the partition, peculiar sectional fur-

FIG. 11.

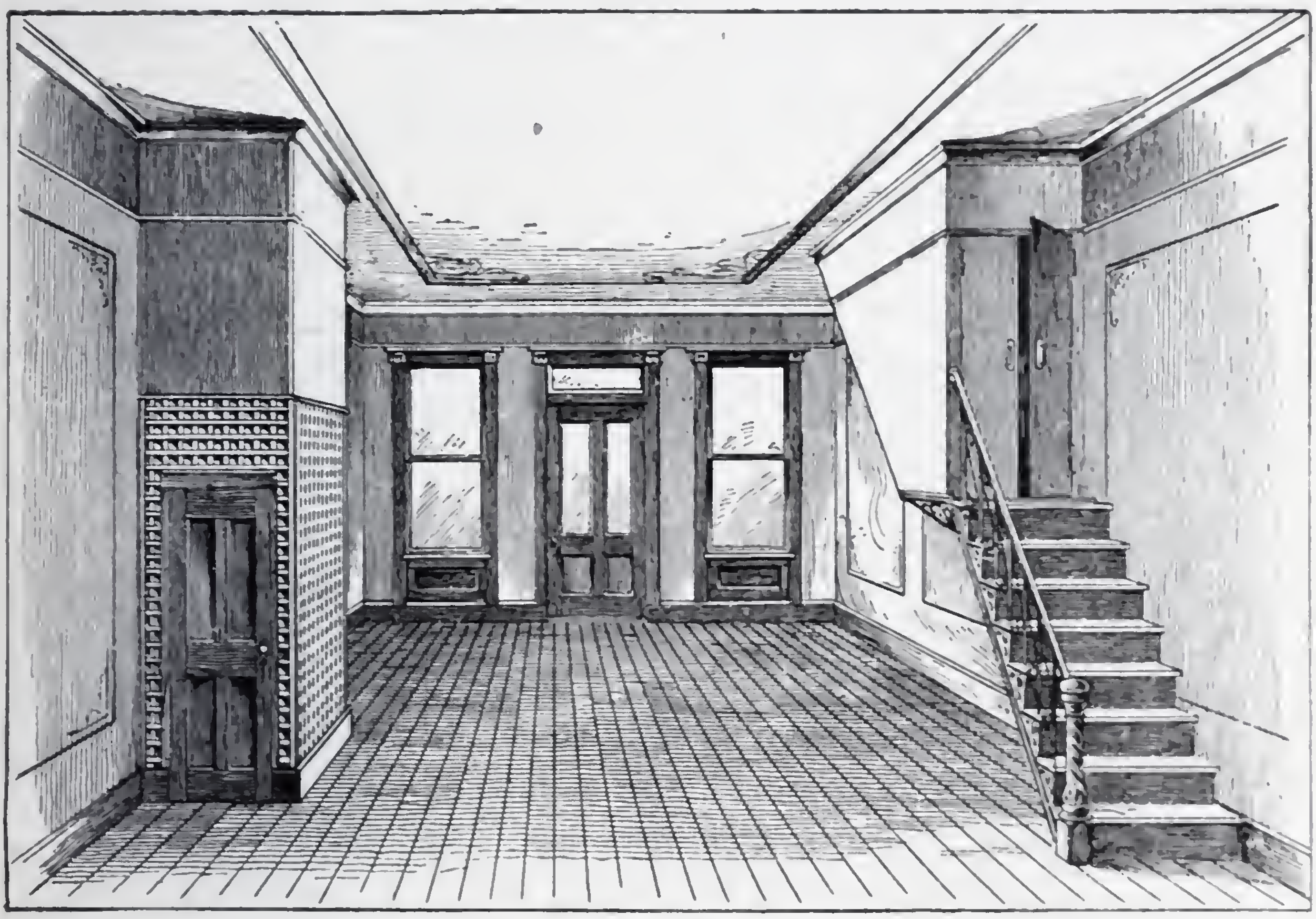


Section of Partition.

ring, $1\frac{1}{2}$ inches deep at say 16 inches centreing. The lathing is wired to them and the whole is plastered. The sections, Fig. 8, show the relative arrangement of the parts. An analysis of the construction shows that we sustain a screen of proven fire-resisting nature say 10 to 11 inches from our heavily-sectioned wood. The first metal binding of our earthy coat is of such character and so arranged that it fulfills its function perfectly, while the furring is of heavier make-up, but yet so light as to do no mischief in an expansive movement caused by great heat. This neutrality is secured by its provisional attachment. The heavier or main supporting members, the I-beams, are protected against sharp heat in the lower limbs or flanges, while their webs and

upper limbs may confidently be counted on to receive nearly the same degree of heat, insuring their remaining straight and normal. No bolts, special drilling, tapping, etc., no precision of setting, are needed in this floor. As a construction it is resilient in a high degree, is not in any sense fragmentary, and as a horizontal plate girder is of such disposition in its parts and details as to be of great strength. Where it is undesirable to use wood, 2-inch or

Fig. 12.



Elevator and Stairway Arrangement.

other proper-sized **T**-iron may be reversed and laid across to receive the usual tile, which, in turn, receive encaustic or other final covering, as in Fig. 9. The resilience and other qualities noted are retained in this variation. Between this construction and the usual filled iron joist systems great differences exist in the dead load of floor, of foundation and footing, weight of wall, facility and certainty, the time demanded for erection and the cost.

Fig. 12 is a presentation of the common store-room, but with special treatment of elevator and stairs. Assuming the ceiling to

be of fire-resisting nature, and that these (elevator and stairway), while open below, are perfectly screened off as to their upper portions in the manner clearly indicated, let us imagine a fire to occur in any location in the room. The flame, unable to burst through the ceiling, and not having the usual and ready means provided for its flight and spread to upper stories, and not acting contrary to a great natural law, would undoubtedly find outlet for itself at the upper part of windows at end while the fire was yet at a controllable stage. The spread of fires horizontally in great stores is to be combated by simple screens, hardly partitions, but, like the floor, these must be unimpeachable in character.

Other examples could be given, but these will suffice to show range of application.

As to material, we shall ultimately and at no distant day see metal joist and other like members in even our dwellings. We shall taboo inflammable wood as far as possible in our construction and relegate it and its softness and grained beauty to more nearly an ornamental function, using it for quality, not in quantity.

Architecture to-day, as it always has been, is a composite art, in which artist and engineer go hand in hand for a proper result. In the realm of more nearly pure engineering, exemplified in bridge-building, those who design them do not have them fail through limitations imposed and accepted. Besides the large factor of safety, there is the ethical spirit—the *morale* in the profession—which will not and cannot brook limitation, to invite disaster, and the great structures stand, monuments of a principle of the noblest kind. In the twin art cited, had the builder been equally jealous of his good name, and resisted the unwise—often even the mercenary—demand of the patron, would the record of destruction and loss from conflagration stand as it does? All work of man has an ethical side. When the great Richardson lay dying, no further worldly emolument to be his, with poor hand bereft of its physical cunning, he, with borrowed ones, wove out his unclouded fancies, and the realization, his greatest work, we possess, a Temple of justice, superb, peerless! "Faithful to the end." Cannot we, in our humbler work, be true to

ourselves, too, and, while holding fast to that which is good, be courageous enough to cast off and break away from that which is bad?

Meeting adjourned at 9.45 P.M.

J. H. HARLOW,
Secretary.

JUNE 16TH, 1891.

SOCIETY met in the parlors of the Academy of Science and Art, at 8 P.M. Forty-two members present. W. L. Scaife was requested to preside.

Mr. C. Davis reported that the Library Fund was very low, and suggested that those who felt so disposed could or should donate toward this fund to pay for the binding of the unbound volumes now on hand, the donations to be sent to Mr. C. Davis, or to the treasurer.

There being no further business, the paper of the evening, on Bridge Design, was read by Mr. Harry J. Lewis.

BRIDGE DESIGN.

Bridge designing may be roughly divided into two classes,—general and detail.

General design begins with a study of the relative merits of different sites, in case the crossing is not fixed by outside circumstances.

An accurate plan and profile of the ground should be prepared, giving, in addition, the contours of adjoining territory. Thoroughly definite information should be obtained as to high- and low-water marks, and the direction and velocity of currents under different circumstances.

The character of the ground should be carefully investigated, by means of borings or otherwise, at the location of all piers and abutments, and to a depth considerably below that of the proposed foundations.

If the crossing is over navigable waters, it will be necessary to consult the interests of navigation in the location, length, and height above high- and low-water mark of the channel spans. This is, however, in most cases, fixed by statute of State or General Government, usually the latter, and plans are subject to the approval of their officers.

It is generally required, that the main channel be crossed by a single span, at a sufficient height to clear all craft at all times. In cases where this cannot be done, draw-spans must be introduced for use during floods, or for the accommodation of the larger vessels.

Any additional water-way can, generally, be filled in most economically by deck-spans, which cut down the masonry by the depth of the truss, at a slight additional cost of the same.

Beyond these, grade can be carried to the general level by means of wooden or metal viaduct.

In the design of work when the length of span is not determined by outside circumstances, it should be so adjusted as to bring the total cost of masonry and superstructure to a minimum. In this, however, the limits are easy, as moderate differences in length of span affect the total cost but little.

The subject of foundations must be considered in direct connection with the length and location of span.

In determining this uncertain, and yet most important, part of the work, the borings before mentioned will be of great assistance.

In company with the superstructure, foundations have been in a continual state of evolution for some years past, until, at present, the designer has several forms from which he may choose, or modify, to suit the particular case.

The simplest form of foundation under water is, probably, the timber platform, with or without concrete filling, and placed with its top below low-water by means of a pit or coffer-dam.

This can only be used, with safety and ultimate economy, where the soil furnishes a good bearing-surface at an easy depth below low-water. It should never be used except, for abutments on streams with easy currents, and, for piers resting on solid rock at a moderate depth under water.

In deep water, where the bottom is good and easily levelled off, the timber crib has been used with fair success in many places.

Another device, for similar cases, is the timber platform, with detachable sides, forming a sort of water-tight scow, in which the masonry is built till the platform touches the bottom and the stone-work is above water, when the sides are removed leaving the platform in place.

All the above forms are open to objection if placed in midstream with strong currents, except on rock bottoms, as they are liable to be undermined, and if protected with riprap the waterway is considerably diminished.

Where the water is of medium depth, and the bottom shifting and unreliable, but underlaid by firm strata of clay, or other penetrable material, piling is generally used to secure a bearing beyond the reach of undermining.

Pile foundations are of three general forms: In one the piles are driven inside a coffer-dam, which is then pumped out, and the piles sawed off and capped over with a timber platform below low-water. In another, the piles are driven in the open stream, sawed off under water, and the platform and masonry are lowered upon them by means of guide-piles and hoisting tackle.

In the third, the piles are either driven inside a boiler-iron tube, or, it is afterwards lowered over them and filled with concrete. This latter is quite economical in localities where material is expensive, and, if well done, makes a fairly good pier.

There are, probably, more of the better class of bridges resting on pile foundations in this country than on all the other forms put together; and so well have they stood the test of use, that piles have come to be regarded as a sort of panacea for all engineering difficulties.

There are, no doubt, bridges in every-day use in which the current has carried away the material under and around the timber platform and left the pier standing, supported by the piles alone.

In passing, a remark as to the legitimate use of piles may not be out of place. There are few instances of failure where piles have been driven to a good depth, capped over close to the ground and loaded in the direction of their length, but when called upon to resist horizontal loads, amounting to a large percentage of the vertical, they are liable to shift position if the material around their tops is not firm.

In the most important works of later years, the practice has been to carry the foundations to the solid rock by means of some of the methods using compressed air. This has already been successfully done to a depth of about 114 feet below the surface of the water.

Another method of securing deep foundations is to sink an iron caisson, or timber crib, by dredging from above. This, however, lacks the certainty of a good bearing on the bottom, which is secured by the methods of compressed air.

Finally, as to foundations in general, it is sound economy, in the long run, to be a spendthrift under water, even, if circumstances make it necessary to be a miser above.

In the matter of masonry it is doubtful whether we have progressed greatly, if at all, beyond the works of the ancients. With the assistance of the hoisting engine of modern type, we can probably handle masonry more promptly than ever before ; but a speed in setting, which places any considerable load on the mortar joints before they have had time to take considerable set, is of doubtful utility, to say the least.

The general form of truss, which combines the maximum of strength, stiffness and economy, is a matter about which the doctors disagree somewhat. A few points, however, are common to nearly all the best modern designs for through bridges.

The end posts are inclined, and run across one or two panels as the span is short or long. The lower chord is straight, with the possible exception of the end panel, which may be inclined to conform to existing masonry. The upper chord is straight in short spans, where the difference in strain is not great from end to end, but in long spans it is curved to something near an approximation of the parabola, but with straight segments.

Some designers deflect the chord at each panel point, but it is doubtful whether they secure much ultimate economy over those who content themselves with fewer deflections and simpler details. The latter class, in spans of medium length, simply incline the chord each way from the centre, and secure a good share of the economy arising from increased centre depth, with very little sacrifice of simplicity of detail.

The compression members of the web are placed vertically, and the floor beams secured to them as rigidly as possible. The tension members in the web cross a single panel, and in long spans a sub-system is used to reduce the length of the principal panels. The old, short panel and shallow stringer have given way to the long panel and deep, stiff stringers, braced so as to form an independent plate girder span.

In deck trusses there is seldom very much latitude as to outline of truss. The inclined end post is most economical, if it can be used. The top chord is straight, and often carries the floor direct, or the floor beams rest on top. The bottom chord may be curved with considerable economy where the clearance below will admit.

There is no particular form of web adhered to, the triangular system often giving as good results as any.

In passing from general to detail design, a word as to general plan and specifications may not be out of place, as their proper function is as a sort of link between the general designer, representing the owner or purchaser, and the detail designer representing the contractor.

The general plan should show all outside conditions, depending on the particular location, which it is necessary to meet, and, at the same time, give an outline of the form of structure desired. Further than this it is hardly desirable to go, unless a full detail plan is made.

The specifications should define the conditions, which are necessary to the structure itself, and which are common to all others of its class, viz.: The live load and the necessary data for the calculation of the dead load.

The unit strains for the different materials which will be admitted, and for all the conditions under which they can be used.

The general conditions for calculation.

The details of construction.

The quality of material.

It is probable that, under ordinary conditions, the best general plan and specification is that one which, between reasonable and necessary lines, leaves the greatest possible scope for originality of design in form of structure, details and material.

Between general and detail design there is a strip of disputed territory, which is, sometimes, the scene of very animated contest. This, however, is gradually narrowed as the parties come to understand each other's position more fully.

The province of detail design is, generally, to take up the work where the general designer leaves off, and localize it to the practice of the particular shop in which it is to be executed.

To begin with, the detail designer should have sufficient experience to rightly interpret the general plan and specification.

He should be acquainted with the "red tape" of the office.

The different manipulations of material in the shop must be carefully studied. The laying off, by template or multiple punch,

must be predicted beforehand, and the rivet spacing adjusted accordingly. Care must be taken not to exceed the capacity of the punch, shear, riveter, planer, boring mill, lathe, crane, furnace hammer or other tool, or the work is liable to come to a sudden standstill.

There is often a choice between different methods of execution, as for instance, an expensive forging, of which only a few are required, may be replaced by a riveted detail of slightly greater weight, but cheaper in the item of workmanship; and again, a clumsy riveted detail, which is often used, may be reduced to a standard forging and made in quantity with economy.

Leaving aside the question of tools and machinery, it will sometimes be found that what is comparatively easy to execute in one shop is, on account of what our friend Herbert Spencer terms the "Personal Bias," very hard to get done in another. To speak more plainly, few shops, which are old enough to be capable of thoroughly good work, are entirely free from over-conservatism, and sometimes even a trace of fogyism.

The designer should be thoroughly posted as to the capabilities of the mills, so as not to inclnde anything which is not a commercial possibility; and, while he should confine himself to the more used, and, therefore, cheaper shapes, yet he should be thoroughly conversant with the special shapes, which may help him out of a tight place.

It is always best to make the variety of shapes as small as possible, as this greatly facilitates the obtaining of a complete bill of material. Shapes are more readily obtained if all of one weight, which remark applies also to the cross-section of bars, but universal mill plates may be varied at will, providing each item will use up a billet of moderate size.

Hence, in making up sections containing plates, it is better to vary them by changes in the plates than in the angles or other shapes.

In this connection we might mention the tendency to use material capable of resisting high unit strains, and which at present is confined mainly to the longer spans.

This results in cutting down the amount of material necessary

to carry the live load, and also in a reduction of the dead load. This increase in unit strains and the consequent raising of requirements as to quality of material, if carried too far, results in an increased cost per pound, which considerably diminishes the apparent gain, as the mills are quite prompt to take revenge on the individual who gets too far ahead of the procession in his specification for material.

It is not improbable that medium steel will be used before long under the same specification for workmanship as iron, for the reason that it can be cheaply produced of such quality that a punched hole in it will stand even more abuse in the drifting test, and it can be punched closer to the edge, without apparent injury, than iron of the same dimension.

While the details of the truss differ in almost every individual design, yet the general principle is in many cases the same, but worked out differently by different designers.

The end shoe receives its load from the pin exclusively and is free to move through a small angle without obstruction, in order that the truss may be free to deflect, and the shoe to adjust itself to an even bearing on the masonry without producing bending strains in truss members. A cellular bottom, with vertical ribs crossing the direction of the bolster plates, is necessary in heavy span to distribute the end reaction evenly over a sufficient area of masonry.

With regard to the hip joint it is quite generally agreed that provision should be made to transfer all strains through the pin; but while some designers leave the joint between cord and end post open from one-quarter to one-half inch, others make the contact as perfect as possible. The latter is certainly a neater finish, but is open to the theoretical objection, that it may cause bending strains in case of unequal deflection, and should not be attempted except where first-class workmanship can be secured.

In the straight cord joints most designers assume the strains to be transferred through the abutting ends, and only provide enough splice plates to hold the members firmly in position. Sufficient pin bearing is provided to take up the maximum increment of strain produced by the web members.

The end connection of the intermediate post to the pin is one of the most troublesome details in the whole truss, for everything else seems to have the right of way over it, through it and around it. The connection is often in such close quarters that the pin can only be reached by a flat web, and such a variety of post sections is used that it is often quite a problem how to join the two without leaving a point weaker than the main member.

Tension members in themselves are easy to handle, as they are of two general forms, the bar head and the loop eye; but the designer will sometimes find himself put to his trumps to find room for them and pack them so as not to converge too sharply nor produce excessive bending in the pin.

The old practice of giving a considerable camber to the truss has been quite generally abandoned, and at present only enough is put in to keep the pins of the loaded chord from dropping below a straight line joining the two end pins when the span is fully loaded. There are two or three methods in general use which are very close-approximations, but the details of these are too intricate to admit of discussion in this paper.

The top struts are usually built the full depth of the chord and rigidly attached to it, top and bottom. There is a considerable variety of opinion as to the mode of attaching top lateral rods. Some connect them to a wing plate on the chord pin, while others attach them in the plane of the top flange of the struts, and give this flange sufficient section to carry the full strain. In long spans where considerable section is required, a good plan is to use a double system top and bottom. Some very good work of later years has been built with rigid diagonal members in the top lateral system, but this is quite likely to prove troublesome in erection.

Portal bracing under heavy strains should also be attached to the top and bottom flanges and not to the web. One very common fault of curved chord bridges with long end posts is to put a splice in the post, just about the point of maximum bending from the portal.

Intermediate sway bracing is of rather doubtful utility, except where the column length can be bisected in both directions.

The arrangement of the lateral system of the loaded chord in

long spans which require large sections in the lateral system, so as not to produce bending moments in the posts and beams and transfer the longitudinal strains symmetrically into the chords, furnishes one of the most troublesome problems in the whole truss. The first condition to be met is, that the centre line of the diagonal members must intersect the centre line of the beam or cross-strut in the vertical plane through the centre of the chord. With a proper arrangement of details, this relieves the beam from bending strain. As the diagonal members cannot be made to intersect the centre line of chord in the horizontal plane, and at the same time fulfil the above condition, some device must be used to avoid or counteract the bending in the post. When a single system of rods, above or below the chord, is used, the bending in the posts is taken care of by rods from an adjacent chord pin to a point well up in the post. Again, a double system of rods is sometimes used, in which one set is connected above and the other below the chord to a U-plate, which bears on the centre of the pin. Another very neat arrangement is the bifurcated lower cord in which the diagonals run to the theoretical centre lines of the chords, which are themselves divided and connect to pins above and below the beams. This, however, necessitates a rearrangement of the truss members, which is troublesome and expensive.

With regard to floor beams, it is quite generally agreed that they should be rigidly attached to the intermediate posts wherever it is possible, and in such a manner as to load the post symmetrically. The strains from the lateral system should, as far as possible, be taken up by the lower flanges.

The arrangement of longitudinal stringers in long spans forms quite an intricate problem on account of the differential lengths between stringers and chords. When stringers with rigid attachment between floor beams are built to the chord length under full load, erection is rendered difficult, and the beams must be bent transversely in order to assemble the truss. Some designers overcome this difficulty very neatly, by treating each panel of stringers as an independent span, with provision for expansion. In using this detail it is best to attach the stringers rigidly to one side of each beam, in order to counteract any tendency of the beam to

get "in wind" under unsymmetrical loading. The above difficulty does not manifest itself in short spans, and in these the general practice is to fasten the stringers rigidly to the webs of the beams.

The use of metal stringers in preference to wooden floor joists in city bridges is increasing, probably owing to the greater strength of floor system rendered necessary by the various schemes of rapid transit.

Erection should be looked after very carefully in the design, as money can be thrown away more lavishly here than anywhere else. The truss should be self-supporting as far as possible, to avoid extra falsework and shoring up of individual members. The connections should be free from intricacy, so that the minimum number of pieces have to be supported, in order to assemble a self-supporting section.

From the foregoing it would appear that the intelligent designer must combine theory and practice, and, for that matter, the only way to avoid the old-fashioned conflict between the two is to combine them in one man, along with a proper judicial frame of mind.

This recalls the remark of a young engineer, who said: "The engineer of to-day should be a cross between a first-class mechanic and a college-graduate; not a bad parentage, by the way."

Discussion.

W. L. Scaife: You have heard Mr. Lewis' interesting paper. There are quite a number of bridge engineers here, and from the number of designs of bridges about Pittsburg, there should be no difficulty in raising a discussion as to the best principles to be applied.

Theodore Cooper, of New York: I came here this evening to listen, rather than to talk. I have listened to the paper by Mr. Lewis with much interest. As the purpose of such meetings of professional men as the present one is to draw out criticism and difference of views upon matters of mutual interest, I would add my mite to the discussion.

Bridge designing covers not only the designing of the various

elements of a bridge structure, but the selection of the proportion and relation of all these elements to make a completed whole.

It requires not only a sound theoretical knowledge of the action of the forces in and through such elements, but a large practical knowledge of construction and good common sense.

A person may have a thorough knowledge of the mathematical solution of the strains, may be able to make a careful and accurate drawing, and may have an extended knowledge of how the different joints and elements can be made, and with all may grow gray-headed and not know how to design. Or, in other words, may never be able to so combine his knowledge as to produce a harmonious and satisfactory result.

The designing of a machine or any engineering structure does not consist in simply a knowledge of the parts of such structure. Important as this knowledge is, something more is necessary—an ability to so combine the essential parts of a structure to make a harmonious whole. In designing our bridges, we nearly always have some restrictions, due to the particular location, span, panel room, or some feature affecting the erection.

Now to select the form and proportion of panels and depth which will produce the best result, we are compelled to depart frequently from desirable theoretical proportions for certain parts, in order to avoid undesirable results in other directions. For instance, we cannot always select the panel length which will give a desirable inclination for our diagonal web members, owing to the resulting undesirable inclination of the lateral system. It becomes necessary, therefore, to balance the relative importance of the proportions upon the several parts of the structure, and the facility with which the several parts can be connected and made to work in harmony, before we can select our skeleton design.

A thorough knowledge of detail construction, and of the effects of changing proportions is, therefore, very essential.

I cannot better illustrate how not to do it than by referring to that great structure, the Forth Bridge, as clumsy a structure and as awkwardly put together a piece of engineering, from the American point of view, as was ever constructed. How was this bridge designed ? The skeleton outline and form of the principal

members were all decided upon without apparently any idea as to how the parts could be connected together to form a whole. It was decided to make all the principal members cylindrical in shape, on the belief that this section would give the greatest strength.

The question afterwards came up, how were these tubes to be connected together. Now imagine the junction of four tubes of different diameters, 12 feet, 8 feet, 5 feet, and 3 feet, meeting at different angles and in different planes.

Mr. Becker said they found it impossible to work out this junction on paper. They then modelled it in clay. After modelling it, and examining the model, they decided it could not be made, and that it would be necessary to flatten the ends of these round tubes into square ones. Now if this difficulty had been considered at the first, it probably would have altered very materially the forms of the members and rendered the design a less clumsy one.

American methods of design, construction, and erection would have saved, in my opinion, 50 per cent. of the cost of workmanship of this structure.

EMIL SWENSSEN: I did not hear the paper, as I came in late; but Mr. Cooper's remarks called to my mind something that very often happens. We often get strain sheets from outside parties to work up the details from and construct the bridge, and we very often find that the design has not been carried to the point that it should have been. For instance, we find when we want to design the eye-bars, that the top chord is too shallow or too wide. I have now one bridge in mind in which all the eye-bar heads had to stick out on the top chord from one-half to one and one-half inches. We had to slot out the holes, and that was not an English but an American design.

And then, there is a great deal of trouble to the bridge companies in the ideas of some of these persons. They are often unwilling to take their advice, even when it is better for them on the face.

W. L. SCAIFE: Perhaps, in connection with bridge designing, Mr. Cooper might give us his ideas as to the materials which

should be used. Some time ago there was a discussion in this Society as to the effect of temperature on bridge material, and the general consensus of opinion seemed to be that a low temperature affected considerably the resisting strength of steel and iron, and that the effect of temperature should be taken into consideration in writing specifications. A committee was appointed to investigate the matter, but like many other committees, has failed to report. However, from the facts produced, the subject seemed to be an important one, and the inquiry arose as to why railroad engineers paid so little attention to it in their specifications?

THEODORE COOPER: I do not doubt that in the use of iron, where we are using it to its maximum strength, that cold has a very great effect in making it more treacherous at certain temperatures. It is more treacherous at certain temperatures than at others, but I do not believe it will have any effect at all within the limits to which we use iron in our permanent structures, which is a distinctively different thing. I mean a permanent structure within reasonable bounds, because nothing is permanent. Now, shapes and bars that we are constantly overworking I have no doubt are very seriously affected by severe cold, but permanent structures, where we are supposed to keep our strains within the elastic limit so that there is no permanent change in the form of any member for any load that may be put upon it, I do not think are appreciably affected by cold. I do not think that the elastic limit of the material is changed to any appreciable amount. I have not seen any evidences to show that it was. Of course, we all know that the elastic limit is somewhat of a fleeting thing. It is not a fixed thing. It varies in its location and in its extent constantly. The old humbug of fatigue of metals you have all heard about. It has been the basis upon which a great many young engineers have worked. It was largely used by German engineers also until recent times. It is a hobby based upon a certain series of experiments that were wrongly interpreted. It is a most unscientific and ridiculous thing to talk about the fatigue of metal.

Metal either wears out or it does not. It doesn't get tired. The whole thing was based upon a series of beautiful experiments

by Mr. Wooler, which has been wrongly interpreted. It has only been since more recent experiments have been made that the true interpretation has been accepted, that metal does not get fatigued; but it shows different results under different conditions, for the reason that the standard of reference is changed constantly. A bar that has under a certain strain given certain results, under another strain will give a different result; but the condition of that bar should be measured from the original condition—that is, from the strain you start from.

THOS. H. JOHNSON: Touching upon the question of the effect of cold upon metals, I have the information from members of that committee (I am very sorry that they have never filed a report) that so far as their work has extended, it went to show that the brittleness in extreme cold, which gave rise to that paper and discussion, exists only in what is commonly known as "merchant bar" and similar grades of metal; that the higher grade of metal required, subject to first-class bridge specifications, is, if anything, a little stronger and less brittle when it is cold than in ordinary temperature, so that really we have nothing to apprehend from that source. If we obtain the grade of metal that specifications usually contemplate and call for, it really becomes a question of more thorough inspection.

W. L. SCAIFE: As I understand it, the bars that Mr. Ramsay tested were for a bridge, and from one of our best concerns, some of them being condemned when tested cold, and others of the same lot being accepted when tested at a higher temperature.

THOS. H. JOHNSON: I was speaking of the work of the committee, so far as it has extended. It goes to show that the iron which was brittle belongs to the inferior grades; that the iron which really meets the requirements of our best specifications does not behave so.

A MEMBER: There is one thing I would like to inquire about. In a bridge of good-sized spans, where the top chord is curved, some will say that we have to allow the most space between the upper side of the pin, and some on the lower side. Of course this only refers to bridges with curved top chord, and not with a flat chord. I mean, should the largest space be allowed on the upper side of the pin or on the lower side?

THEODORE COOPER : I think the principal reason why engineers have adopted the plan of cutting that joint away is on account of the mechanical difficulty of making a decent job of it; and we would rather have a joint that we knew to be perfect, which we get by cutting away the chord and letting all the bearing come on the pin, than we do by trying to make a double joint, as we do if we try to make a bevel joint.

I would advise the gentleman to cut away wherever the greatest error is likely to be. I have seen joints made from bevel joints, and when the pin was put in there was no bearing. Sometimes the holes were too large, and sometimes too small. The general opinion is that we had better throw them off altogether.

MR. DEFORT : I agree with Mr. Cooper entirely in this respect. If we have a close joint we have to figure it with reference to both dead and live loads. Inaccuracies in shop practice will never make such an exact bevel that the bevel will be close at all times, or even at any time. If it is closed for the full dead and live load, it will be open if the train is only partially loaded, and of course that will throw a great deal more compression to one side on the upper chord instead of distributing it uniformly over the whole bearing surface ; while, if we have an open bearing, we can always rely upon sufficient surface on the pin—counting, of course, on the reinforcement plates, which we can figure pretty accurately, and we can transfer all the strain from the pin.

Now, speaking about cambering, I want to ask the members what they consider the right way to figure the length of the different members. There are three ways in use. The one generally used in Pittsburg to figure the length of the different members, the mathematical length, shortening perhaps the tension members a little, and lengthening the compression members. Of course that will not cause very much trouble in long spans. For instance, in a 500-feet span suppose we take the full dead and live load. If we assume the modulus of elasticity at 30,000,000, and the unit strain at five tons, 10,000 pounds, the elongation will be two inches. That means that the end foot will travel one inch ahead of the end connection of the end stringer with the end floor beam, provided there is an end floor beam. Of course this will

cause a considerable amount of tension on the rivets connecting these end stringers to the floor beams. They should always be attached to the floor beams in such a way that they can follow the expansion and contraction—can slide, in other words.

The second method of figuring the camber is that we take out the stretch or contraction caused by the dead loads. According to my opinion, that is the best way. Of course we are then sure that, out of that condition of loading, the bridge will be in its normal condition. Of course we assume a certain camber, but this method is followed by certain bridge companies.

Another method is that we consider the truss or the chord that carries the floor, under the full load, horizontally or nearly horizontally, and then the members are figured for the maximum loads they are intended to carry. Now we well know that maximum stresses in the different members occur in the different loadings. For instance, the chord members receive the maximum stress for full loading of the bridge, while the web members receive the maximum strains only for partial loading—so that we really assume the strain, under any condition, for full loading. We of course take out the necessary amount for the chord members, and we take out so much in the web members, and I think that is wrong. I would like to hear somebody else on the subject.

Emil Swenssen: The last method that the gentleman spoke about is probably the best, if, instead of taking the maximum load, you would take the uniform load on the structure, and find the different strains and different members as the result of that uniform loading, instead of taking the maximum load—which has been the way it has been done in some large spans erected lately.

Mr. DeFort: I would like to ask Mr. Swenssen what he considers the uniform load?

Emil Swenssen: It is different in different conditions.

H. J. Lewis: To come back to that subject of the pin joint, I would like to inquire if anybody has either made or heard of any observations of the actual behavior of that joint under load—that is, a load from one end of the span to the other. I do not know whether there is any definite information on that. If there is I would be glad to get it.

THEODORE COOPER : I have sat on many a bridge and watched it. I do not think there is very much motion on ordinary spans. It is pretty hard to observe it. It depends on whether the members vary ; whether the chord has been cut away ; and then they sometimes put on splice plates. On ordinary spans the motion is very slight.

EMIL SWENSSEN : There is another reason why that joint is left open. That is the convenience of erection, for putting the last sections of the chord together. Engineers prefer to have that opening.

MR. DEFORT : I wish to add that when we make a pin joint we make it so that the two ends will never meet, so that really does not make any difference—that is, with reference to the radical opening ; only, of course, it is of great convenience in the matter of erection.

On motion, adjourned, at 10.30 P.M.

J. H. HARLOW,
Secretary.

SEPTEMBER 15TH, 1891.

THE Society met in the parlor of the Academy of Science and Art at 8 P.M.; twenty-eight members were present.

President T. P. Roberts in the chair.

The minutes of the last meeting were read and approved. The applications for membership of W. A. Clugston, M. S. Wickersham, and W. H. Jennings were received, and they were elected to membership. The President read a letter from Mr. Morgan stating that owing to illness, he could not be present to read his paper. There being no other business, Mr. Davison was requested to give the Society some information in regard to the new Sixth Street bridge.

After which the Society adjourned.

J. H. HARLOW,
Secretary.

OCTOBER 20TH, 1891.

THE Society met in the parlor of the Academy of Science and Art at 8 P.M., with thirty-seven members present.

The minutes of the last meeting were read and approved. On recommendation from the Board of Directors, Messrs. F. G. Tallman, M. B. Kelly, Frank Rhea, and George T. Richards, were elected members. Captain A. E. Hunt, on behalf of the committee to the World's Fair Engineering Congress, reported progress.

CAPTAIN HUNT said: Touching the action of this Society with the other engineering societies with reference to the World's Fair and the engineering congress, I have to say that the organization has been further perfected since having made a report to you, and a president, Mr. Octave Chanute, and an executive committee have been appointed. Those members who were appointed by the various engineering societies to represent them in the preliminary meetings have been elected as associate members of the official organization of the World's Fair Auxiliary Congresses. I have been appointed a member undoubtedly from the fact of my having been a member of this Society and representing it in the preliminary meeting.

The General Committee that has thus been formed has an official standing now, more than the one which we had before. No general meeting has been held, but I understand there will be one in the course of a little time. No general plan of action has been decided upon further than the report which I sent to be read here at a meeting at which I was unable to be present.

Therefore, all I can do is to report progress. There will be in the course of a month or two a general meeting of this Committee, at which time some definite plan of action will be formulated. So far I have not found that there has been any plan made for raising the money necessary from the various engineering societies to pay for the headquarters at the Columbian Exposition, and for the congress. It is to be hoped that some plan will be made that will be applicable to all the societies. As I understand it, as a committee from this Society, and representing it, I have no

power or authority to contract any indebtedness for the Society, simply to report to you what plan of action they may suggest. I hope to be able to do so soon.

Mr. Roberts: Has there not been presented an outline of the sphere of duties in a general way?

Mr. Hunt: That has already been done; the Society has on file the report I submitted upon this matter; the same data has also been published in all the leading engineering papers. There has been no official meeting since then. There was one small and an impromptu meeting in New York at the Engineers' Club which I attended, with the idea of getting a separate congress, or a separate department for engineering. The department of engineering is lumped in with several other departments, some of them very cranky in their ideas. We think the science and profession of engineering is of sufficient importance that we should have a separate department. The action that was taken at this meeting was to draw up a paper and send it forward to the management of the World's Fair, and I think our point will be successfully made. We shall probably be able to get a separate department for engineering, and we shall have separate rooms or a building will be alloted to us for headquarters, and a separate week's time in which the Congress can be held.

The paper of the evening was then read by Mr. D. Ashworth, on

STEAM-ECONOMY IN ROLLING-MILL ENGINE PRACTICE.

The pen of the historian impressively informs us that in the palace of Fontainebleau there still remains the table upon which the great Napoleon signed his abdication. Tourists and lovers of history look upon it with awe and reverence. To the reflective mind how the imagination reviews the stirring scenes of the beginning of the Nineteenth Century: Arcole, Marengo, Jena, Austerliz, and St. Helena, pass before us.

In the parlor of the American Society of Mechanical Engineers in New York there is also a table. The inscription upon the plate

informs us that it was the property of Robert Fulton, and upon it was conceived and developed the principles which gave birth to the mighty power of steam navigation. In the city of Savannah, the writer, a few years ago, looked with awe and reverence upon a steam-engine built by Boulton & Watt, England.

To the devotee of science what a troop of ideas flit before us as we look upon these two objects. The first, of Napoleon, is of grim-visaged war, devastation, and destruction, and "man's selfish ambition." The latter is stamped with patience, perseverance, and the application of genius, which gave birth to the great uplifting of the people, and the rapid strides in civilization surpassing all other affairs in the world's history, by the practical application of the steam-engine and steam navigation, brought about by the genius of James Watt and Robert Fulton, to which we subsequently add, with feelings of pride, Robert Stephenson.

It is not our purpose to enter upon an historical study, at this time, of the earlier struggles of those before this period. Although always entertaining and instructive, limited time precludes our entering upon their experiences, but the genius and indomitable perseverance of James Watt we must recognize, and cannot but exclaim, "'Tis wondrous strange!" that all the great principles, properties, and desirable features in steam-engineering, were fully recognized by him, and although the never-ceasing cycle of time has added another century, we have simply been refining, by our improved appliances, the leading principles to which he gave his work and attention, even to our most modern application of compounding. To confirm this, we have to recognize the following summary of the principles which he recognized and discovered, and as far as the crude condition of the tools and craftsmen of the time permitted, put into practical operation.

He recognized the importance of the condenser, thereby making the engine at once double acting. He invented the parallel motion, also, the ball-governor, the indicator, and numerous other features, all of which show us conclusively that the importance of the efforts to overcome the insidious enemy, condensation, was constantly before him. That he was fully cognizant of the laws governing the expansion of steam, the application of his indicator

shows; and in all the years that have passed the improvements upon this instrument have simply advanced in refinement to keep pace with the advancement of the engine itself, the principles and application remaining the same.

Economy.

The subject of steam-economy in engine practice has occupied the attention of prominent engineers and students through all these years; it has always been recognized that there were fields to conquer in this direction. By reason of the stirring activity in commerce and manufacturing, and especially since the rapid advent of the electrical application in lights and metres, the advance of refined steam-engineering has been almost fabulous in the ingenuity and the skill brought forth.

The fundamental principle of economy in steam-engine practice is simply to use the steam as hot and dry as possible, and after it has done its work to get it out of the way as quickly as possible. This is the simple way of expressing it. The multitude of efforts and legion of applications each and all converge to this central idea. In the New England States, especially, largely engaged in the manufacture of textile fabrics, and the marine service, were the places where close attention was given to this matter, and for a long period of time almost exclusively so. In the cotton districts it was principally brought about by the transition from the primitive water-power to steam which, as can readily be perceived, demanded close and economic results, and, as important, if not paramount to all else, close uniform regulation.

The advent of the Corliss and Sickles drop rapid valve movements was the great bound toward the ideal of cutting off sharply and quickly, resulting in obtaining the full benefit of expansion. These were followed by a number of other types of automatic engines which, by movements peculiar to themselves in certain lines, have equalled, if not surpassed, their predecessors. So refined and perfected did these engines become that they became almost universal, not only in America, but in all other nations, a fact which should challenge our patriotism and pride.

Yet, notwithstanding the gratifying and favorable results of this

advance in the right direction, as described, there still remained, in many sections of our country, a seemingly tenacious clinging to the old wasteful type of engines in all our stationary practice, especially in our iron- and steel-works.

We might safely say that this conservative position or condition was, and is still, most prominent in the Ohio and Mississippi valleys, and tributaries thereto. Our sister States of the North and Northwest are rapidly taking up, with the States of the East, the the adoption of the refined automatic-engine practice. To these people, visiting our locality, these conditions of conservatism partake somewhat of a wonder, but to ourselves, in looking backward, we note with satisfaction, progress. Who, among us, does not occasionally see the old, long pop-gun cylinder in the scrap-yard, a silent but impressive reminder of the past, and as we move about our works, the great number of engines of a more modern type, showing that while we are not at the front in modern practice, we are rapidly moving on. The pertinent question which presents itself is, why not at the front? Why have not these engines of economic automatic type been adopted by us? Why has not steam economy in engine practice received our attention until within a late period? The answer would be that our natural resources for fuel seemed boundless, and in close proximity to the works, in fact, they frequently being at the mouth of the coal-mine; therefore, economy in this direction was of but little importance as compared to other features in manufacturing.

Another factor entered greatly into the question; viz., river-practice. I believe that it is generally accepted as a fact that the most conservative engine practice has been, and is still, to be found upon our Western rivers. The peculiar requirements of this service were such as to bring about these conditions. In the palmy days of steamboats, steamboat engine practice served as a model for all our cities and towns, and upon all disputed points great deference was paid to the steamboat engineer.

While this branch of service is rapidly becoming a lost art, economy of steam was but little entertained in this service, the result being exceedingly wasteful. This practice rapidly found its way into stationary Mill practice. This last feature deserves

our earnest consideration, for upon it hinges many other points. Sometime during 1852 or thereabouts, the Corliss engine was adopted in one of our cotton mills with success, but in our steel and iron works, the adoption which closely followed that of the cotton factory, proved to be a source of disappointment, resulting, unfortunately, in retarding the advancement which, at that period, seemed about to take place.

Yet, notwithstanding this rebuff, engine builders have, in our country, continued to advance in the direction of better workmanship, but were exceedingly tardy in the important point of steam economy. It is beyond question, I think, and conceded by all unprejudiced observers, that in our practice we are consuming from 20 to 40 per cent. more steam for a given amount of work than we should, and this amount as compared to the modern type of engine, not including the compound system. We may well say, "Can such things be and overcome us as a summer's cloud without our special wonder?"

The question which suggests itself now, at this stage, is, with the examples in other fields and the lapse of time, why do we in the eyes of others not familiar with our special work, seem so exceedingly tardy in this direction, and also frequently manifest a tenacious reluctance at accepting the new? Before attempting to reply to this, let us contrast the results of steam distribution as shown by diagrams taken from the automatic and plain throttling engine.

Diagram from Corliss engine, 16 inches by 42 inches at 75 revolutions, with a fair load. (As it would be difficult to see these diagrams in all parts of the house, I will endeavor to sketch them on the board).

Observe, if you please, how close the initial is to the boiler pressure, what low terminal pressure we have, how sharp and distinct the cut-off is, and how closely the expansion follows the Mariotte curve.

Here we have a diagram from a Wright engine, 38 inches by 60 inches at 64 revolutions, while driving the Cable Railway at Cleveland, O. And now, one of a number taken by me from the famous Pawtucket engine last June. The economy of the last has

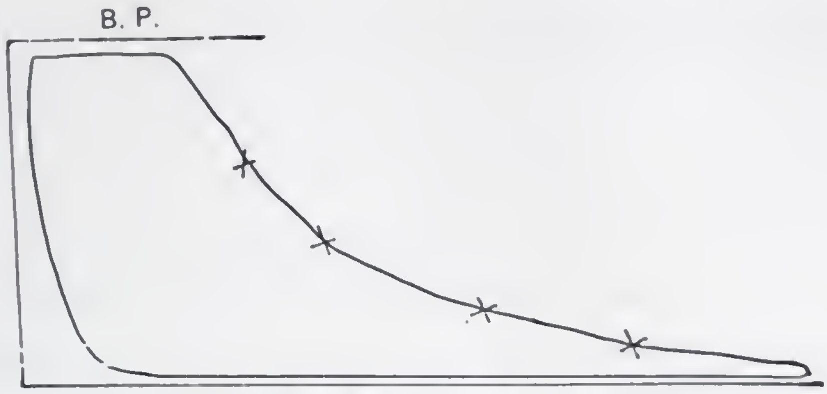


FIG. 1.—Corliss Engine, 16 x 42, 75 Rev.

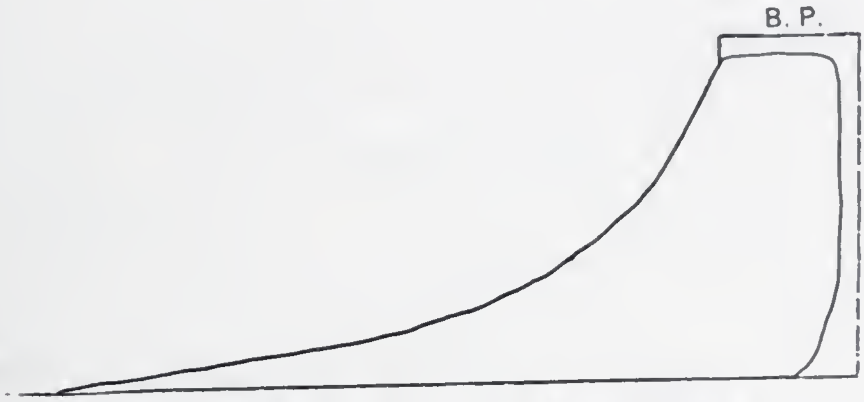


FIG. 2.—Corliss Engine, 16 x 42, 75 Rev.

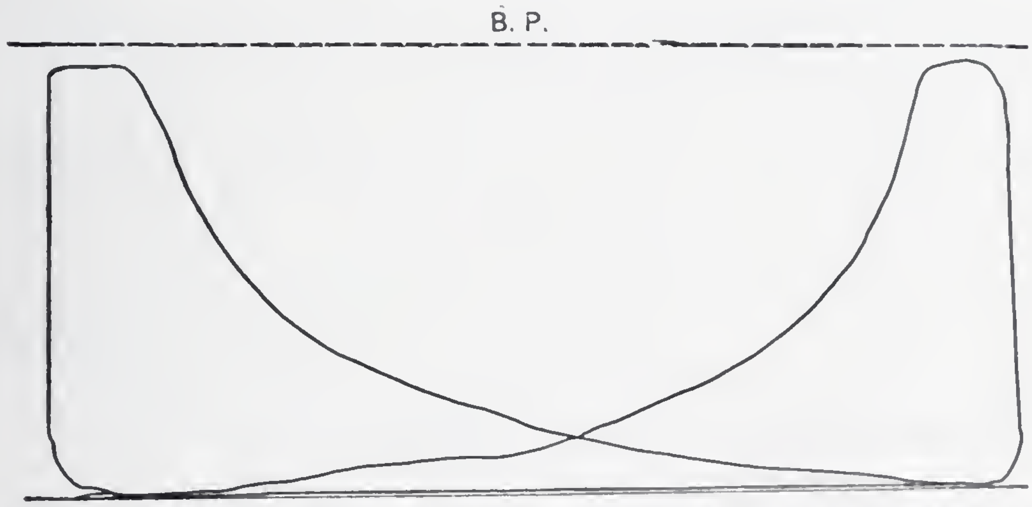


FIG. 3.—Wright Engine, Cable R.R., Cleveland, 38 x 60, 64 Rev.

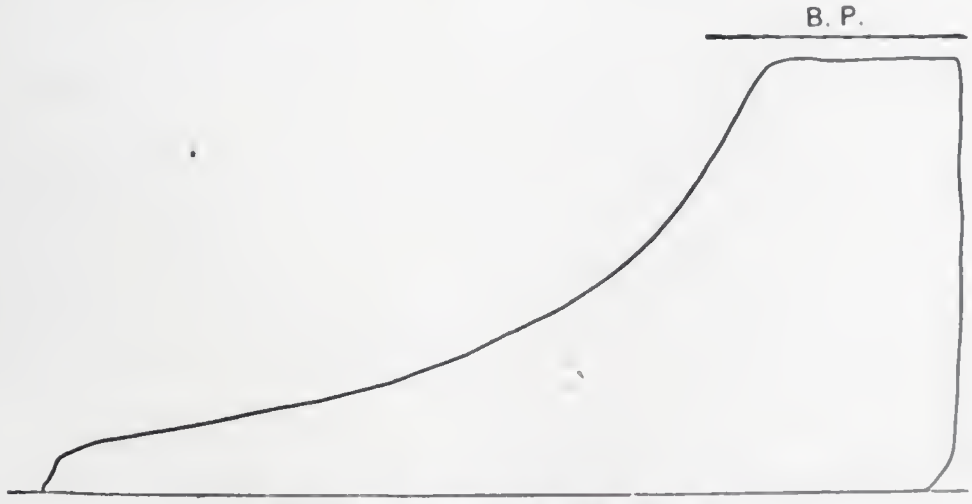


FIG. 4.—Pawtucket Engine.

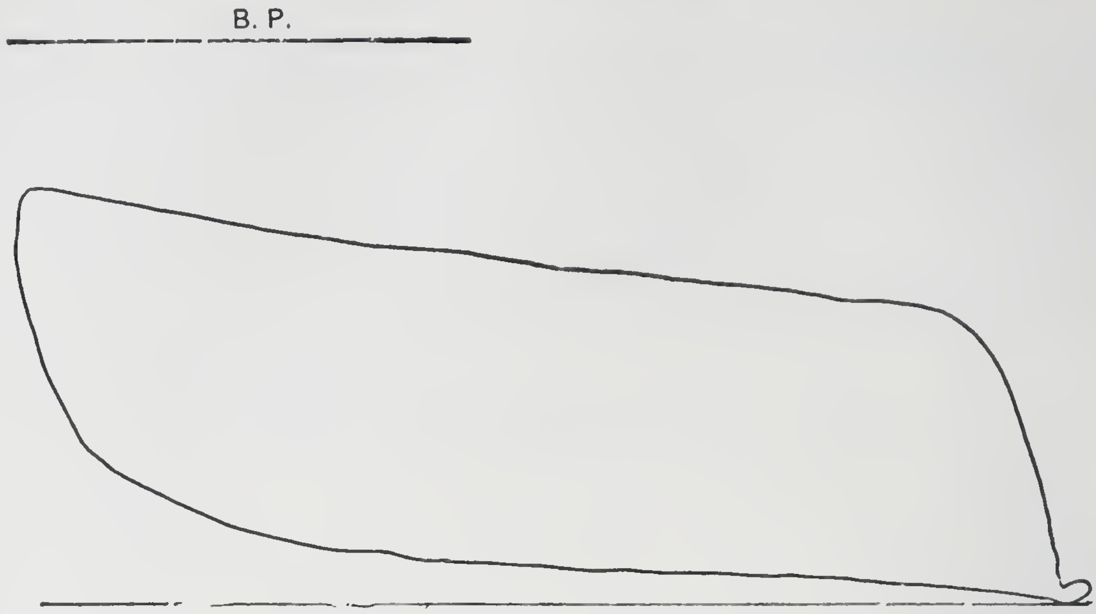


Fig. 5.—Poppet Valve.

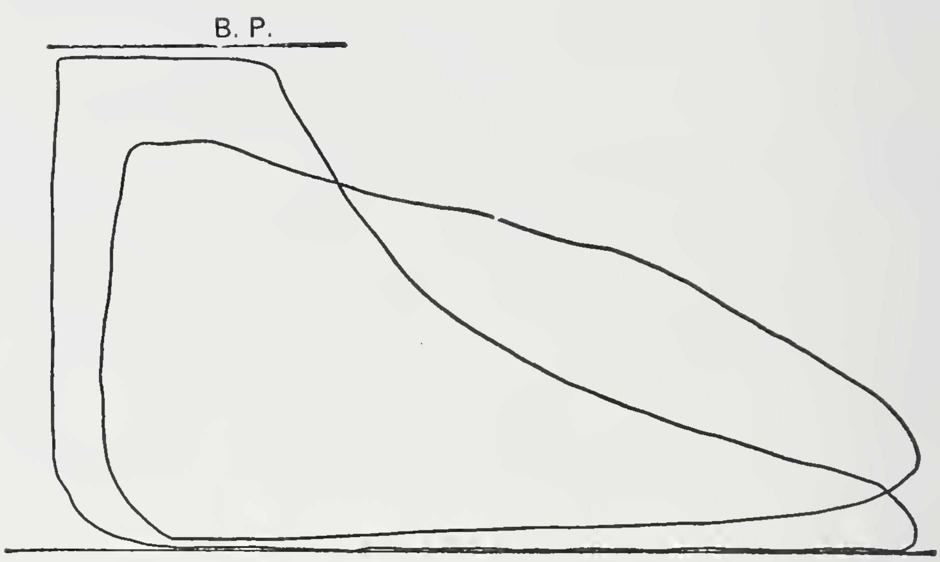
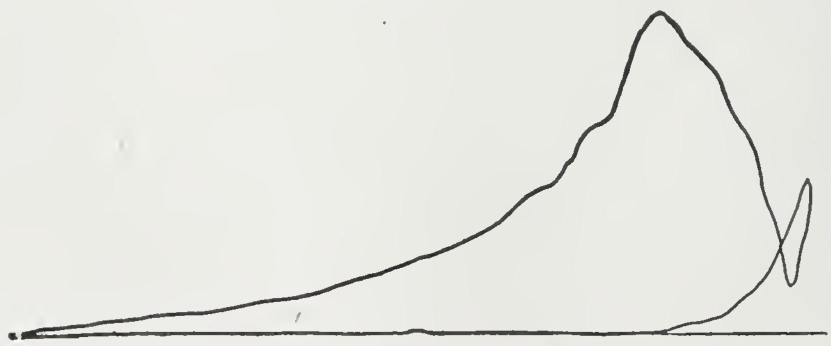


Fig. 6.—Automatic versus Throttling.

Fig. 7.



been a marvel in engineering. Now, as a contrast, I present diagrams of some practice in our own locality. As they are presented, we may well say with the poet, "Look upon this picture, and then upon this." This is from a poppet valve of the steamboat side lever type. Observe how far we are from boiler pressure, and the tardiness of the release and exhaust closure.

This diagram is from one of our best Pittsburg engines for mill practice, massive in proportion, liberal port openings; in general design and workmanship well adapted to stand up to the work continuously, although still lacking the feature of steam economy. Now, that the two types have been presented, let us place them in close contact. Here, we have the ideal automatic, drawn over the actual diagram from our best throttling engine. Notice how we lack the high initial pressure, there being 20 per cent. less pressure than in the receiver close to engine. We also have an exhibit of the wire-drawing throttling process, resulting in a high terminal.

Keeping in mind that the graphical representation of engine economy is high initial and low terminal, here you will observe we have the reverse in the throttling engine, the initial being far too low and the terminal too high. You will clearly observe the volume of steam passing beyond the expansion line, virtually doing no work, but which must be disposed of in the exhaust, and is generally liable to give back pressure.

I have on file diagrams taken by me, showing as high as 50 per cent. of the work to be against its own back pressure. As a curiosity here is an exhibit of one of such character. It is a very simple process to give this a humorous turn; by inverting it we obtain a fair throttling diagram. Such cases I frequently meet, and occasionally a high grade automatic is met which makes a shocking exhibit. Here is a case I was called upon some years ago to make indicator test for the purpose of ascertaining what power if any, was in reserve, and if sufficient to drive a contemplated addition to the department. This diagram was the result. Now, this is from an engine that has a national reputation, but by reason of derangement of valve-gear it was working very wastefully; but after readjustment, which took but a short time, it gave us this

card. It is almost useless to say that there was ample power in reserve. This case goes far to show that there is as great a possibility of having bad results in the automatic as in the throttling practice, unless given close attention.

Referring to the combination of automatic diagram and throttling diagram, our computations show in favor of the automatic, 185 horse-power against 169 horse-power for the throttling. About 5 per cent. more work and 33.6 per cent. less steam. But it is said by some that this does not by any means represent the fair condition, or in other words, the repairs, skilled attendance, and loss of time by stoppages by the automatic, generally far overbalance the steam economy of the best of our throttling engines. Now I am aware that this view is received by the educated engineer and expert in a very light manner generally, which is entirely wrong. It is a very important matter and worthy of our careful consideration, and cannot be flippantly ignored.

We all should realize how great the loss is in an establishment by reason of stoppage of motive power for a short time even; what must it be when the stop is of a lengthy period? I was forcibly reminded of this but a few weeks ago. In conversation with one of our prominent steel manufacturers, this very feature presented itself. Pointing to an engine laid aside in the yard, having been displaced by a more powerful one, he said, "That engine was in operation almost continuously for ten years, and in all that time there was no interruption to work from it, and outside of general work, the expenditures upon it did not run to $10. Upon another occasion, being asked how a certain grade automatic engine was doing that was placed about eight years ago, the answer was, "Oh, that went into the scrap pile long ago." Yet the latter, beyond any question, had the requisites for steam economy.

I say it with feelings of regret, that up to within a brief period the prime cause of the tardiness of the introduction of the automatic type of engines for mill practice has been the placing of engines entirely unadapted for the iron and steel practice. The magnificent automatic engine drives the mammoth flour mills, or the factory of spindles and looms, with splendid economic and

mechanical results, but thus far they have not given continuous service with ordinary attention in the reduction of heavy iron and steel requirements and heavy loads abruptly thrown on and off in a rapid intermittent manner, the shocks and strains being of the most violent character.

We therefore conclude that the steam-engine for our mill practice has yet to be built to cover the requirements of durability and steam economy. From what has already been said, the requirements are, first, massive proportions to receive all shocks and intermittent strains; second, liberal ports for steam and exhaust, free and uninterrupted flow of steam from main pipe, an entire absence of throttling or wire-drawing; third, clearance reduced to a minimum; fourth, quick acting valve movements with least number of parts, cutting off under varying loads from $\frac{1}{5}$ to $\frac{7}{8}$ stroke.

In connection with this we earnestly advise the carrying of higher pressures of steam. This, generally in Western localities, has been well advanced upon, for which we must credit the examples of river practice. It is of the greatest importance. Without it we cannot expect to receive the benefits of expansion, with the great advantage of high initial pressure. Knowing that it requires 1146 heat units to raise one pound of water and convert it into steam at atmospheric pressure, to obtain 150 pounds, it only requires 45 additional heat units, or 4 per cent. additional fuel.

The rapid increase of steam pressure in the marine service has enabled the compound system to be almost universally adopted, and instead of 8 to 9 pounds of coal per indicated horse-power per hour as formerly, we have now vastly better results with 190 pounds of steam, with an expenditure of but $1\frac{1}{2}$ pounds of coal. Now, if this can be accomplished under such limitations of space and position, can we not, at least, do as well on *terra firma?* I firmly believe that the time is not far distant when all these features will be the general rule in our mill practice.

With our vastly improved tools and excellent materials, boiler manufacturers are now well prepared to meet the earnest and growing demand for the higher pressures. With this valuable adjunct now assured, can we not look for the early application of

the multiple cylinder compound engine, thus reducing to a minimum the enormous amount of exhaust steam thrown into the atmosphere with the reduction of the condensation inseparable with the action of the single cylinder?

Another point to which your attention is called, so simple that it at first sight would seem superfluous, namely, proper proportions of piping of steam and exhaust connections, simple, vital and important as they are, the principles seem to be more honored in the breach than in the observance. Many engines, otherwise in condition for excellent results, have met with condemnation by reason of insufficiency of steam pipe or, as I have often seen, a number of unnecessary elbows and turns, which have often suggested the query, if there had not been considerable ingenuity exercised by the erector as to how circuitous it could be made to reach a given point, in preference to a straight line.

Closely allied to this is the absurd propensity that some manufacturers have of placing the governor on top of column or flanged pipe. Said pipe is usually polished to form, as it were, a central point of attraction. This it may be to the proprietor knowing nothing of the principles involved, but to the engineer, that is appreciative of a close regulation, knowing the importance of as close connection as possible, as he looks upon that resplendent pipe, and as he gazes, thinks of the designer, "And still the wonder grew, that one small head could carry all he knew."

This paper would be lamentably incomplete were we to omit the last, but far from least important adjunct, the engineer in charge of the engine. It is a deplorable fact that there is, in this large army of operatives, a large proportion who are utterly lacking in knowledge, skill, and ambition, or any of the requirements to qualify them for such important trusts. I know it to be true that there are a goodly number the reverse of this, but the first-mentioned are vastly in the majority and increasing, I think. What is the cause and how to remedy this condition is pertinent. One of the principal and, I might say, the most prominent, is that pernicious sentence heralded forth by almost every creator of a new engine, boiler, or steam appliance, "No skilled engineer required." And to such a low stage has this become, that proprietors wonder

that there is so little intelligence in the line of stationary engineers.

To create a change in the right direction, to elevate to a higher plane, is a duty incumbent upon all manufacturers, this society, and to all of us individually. To encourage them in their readings and lecture in their societies, assist, if need be, in their maintenance by adding to their libraries and apparatus, and above all things, if possible, to enthuse them with the fact that the field is worthy of their effort, and that we are directly, personally interested in their mental, mechanical, and moral advancement. With the advancement in our steam practice, which we hope is to come, and at an early period, by reason of simplicity of valve gear with durability, with higher intelligence at the throttle, the economy in fuel, through this source, throughout our manufacturing district, will be almost incalculable. After that we will be prepared to conquer other fields by compound, triple, and expansion engines in our rolling mill practice.

Discussion.

Mr. Davison: Is that diagram (referring to one made on the board) intended for a single indication?

Mr. Ashworth: No sir, from each end of the cylinder.

Mr. Roberts: Would you explain, in a brief way, how it comes that Corliss engines, for want of attention, could become so derelict in their duty? What are the points that are neglected for want of skill in the management?

Mr. Ashworth: I think the idea is simply this. The man at the throttle is placed there to start and stop the engine. He usually possesses no understanding of the requirements or brains to know the principles involved in steam-engineering. He knows nothing of the importance of the prompt action of the valves, either in the admission or release, and upon any part becoming dislocated or worn, simply wanting a little looking after, he is in perfect ignorance of what to do. He may run the engine six months or six years and then some successor of his, with some brains about him and ambition just goes to work and develops the proper condition.

It is simply a matter of indifference or ignorance. A slight derangement of a valve will work a radical change in an engine. I have seen men who were interested in the financial part of the business, watching every point to save and yet wasting it away from lack of good engineers or a perfect type of engine.

Mr. Roberts: It would hardly be proper to refer to these engines as automatic, since the best of them require intelligent supervision.

Mr. Ashworth: I will say this, that most automatic machines require far better brains than if they were not automatic. That is my position. I am not in favor of it, simply because an engine is automatic in the distribution of its steam, or feels sensitively every pound of resistance or load thrown upon it. Or let us bring it down to some simple idea. If the engine could speak or telegraph, it would simply say, "I have enough steam" which stops it off. It is not an engine to take care of itself at all.

Mr. Barnes: Mr. Ashworth might, with entire propriety, stiffen up his paper a good deal. What he has said is true, but he has not said the whole truth. Probably he did not intend to try to tell us all of the difficulties under which Pittsburg labors, which will always prevent, in my judgment, the full realization of the best uses of the automatic engine obtainable in other places. I do not think Pittsburg will see its way clear to use the general type of high class compound-engines for a good many years, perhaps never. The rise and fall of our river would be sufficient to render it a very serious question whether any one could pump water for condensers.

Another point which Mr. Ashworth has touched upon. It is an extremely difficult thing—I have found it so for a number of years—to induce builders of engines to believe at all, let alone sincerely, some of the requirements of iron and steel works. They are extremely incredulous as to strength of engines and other machinery needed. I have had occasion to attempt to show this to some who come with a new engine, or about some engine already in use, and I have found them entirely incredulous about it. One case I remember in particular as worthy of mention. I was at Springfield, Ill., some ten or twelve years ago, and had to do with

putting in a 20-inch by 30-inch engine to drive a 12-inch train. The engine was set by a very enterprising man, who came with a request from his employers that he might stay awhile and pick up some points in rolling-mill practice. They expected—sincerely, no doubt—to build heavy rolling-mill engines, and wanted all the information possible. We took a good deal of interest in this man, and I tried to show him what we had found to be the important points of the service. He recognized the propriety of what was told him, in the main, perhaps absolutely. But the only acknowledgment I could get as to the possible utility to him of what had been said was, that if he were to go home and tell the head draughtsman and other people interested about these suggestions, and urge their introduction into the engines they were building, they would laugh at him. Of course, this was not encouraging, but it did not affect the truth of the matter. I have since seen that gentleman,—he is now a Pittsburger,—and he has told me that one or two of the points I had mentioned had been impressed upon him very forcibly in his own later experience in rolling-mill practice. But I repeat that some of the engine builders are apt to be very incredulous of many things which are found essential.

Mr. Hyde: I should like to ask Mr. Ashworth what type of engine he would consider most satisfactory; what type of valve particularly, whether cylinder-valve or slide-valve.

I have some experience, in my own case, with the improper working of engines. In one instance I had occasion to inquire at what point the steam cut off. The engineer told me within an inch or two of the end of the stroke. I think the stroke was 48 inches, but I wanted especially to see, and I found on examination that the cut-off took place when the piston was within three-quarters of an inch of the end of the stroke; consequently, with a low cut-off he got a low admission of steam in the engine.

Mr. Ashworth: I hardly think that is a fair question, as I do not think I am here for the purpose of advertising any particular engine.

Mr. Hyde: Just a general type that will give the best satisfaction.

MR. ASHWORTH: The best type of engine I have found about here has been the piston-valve-engine; but it will altogether depend on the nature of the work you are going to put this engine to. That is about the only way I can answer that question.

MR. HYDE: Less liable to get out of order?

MR. ASHWORTH: Yes, sir.

MR. ROBERTS: I would like to ask Mr. Ashworth—a little off the subject of the paper—in regard to the pumps on our western river boats. The old "Doctor" pumps are said by many steamboat engineers I have conversed with to be more reliable than the pumps you usually see on land,—for what reason I do not know. They are very homely-looking affairs, but they simply seem to be very effective on the rivers, and I would ask if this is a western invention, this "Doctor" pump. It has a fly-wheel and four plungers.

MR. ASHWORTH: Well, I think there are pumps as efficient as the "Doctor." On the steamboat it takes up a great deal less room. I look upon it as an attendant of the steamboat engine and steamboat practice. It is a fact that it is idolized by steamboat men. They take up less room, they are reliable, and their capacity is greater for a given space, but they will use more steam I believe. I know how difficult it is to convince a steamboat man that this pump is not the best pump in the world. I am aware of that, but I do not think it is the best pump in the world. I think there are pumps vastly superior. No one, I think, would think of putting in one of these "Doctors" in a modern establishment where they were turning over a new leaf getting into first-class practice.

MR. BOLE: I would like to call attention to the fact that even without water for condensation, very much better results can be obtained than are now obtained by the average Pittsburg engine. Mr. Barnes's remarks might convey the impression that without condensation it is difficult to produce better results than at present. One step in advance is to introduce a much better system of steam distribution, and this is readily accomplished by the automatic engine when properly designed and constructed.

It is an easy matter to show by indicator diagram why the

automatic-engine will "lay in the shade" the old time throttling-engine. A very important point, too, when aiming at economy in a steam-engine, is the selection of the proper size of engine to do a given work. The available boiler pressure is an important factor in this consideration. I have one case in mind where an engine whose cylinder was 18 inches diameter, the stroke 24 inches, the revolutions about 80 per minute, developing about 50 horse-power, was replaced by a much smaller engine whose cylinders were $8\frac{1}{2}$ inches diameter, stroke 8 inches, running at 375 revolutions per minute, and the steam consumption was reduced almost two-thirds. The same amount of machinery was driven by the small engine for about one-third the coal burned previously. The coal saved in a few months by that change was sufficient to pay for the new engine. The old engine was a fairly good one but was much too large for the work it was doing, and the amount of steam condensed in that large cylinder and thrown out through the exhaust pipe without producing useful work was enormous. On the other hand, there are many instances where engines are used which are too small for their work, and this is also a source of waste. Such engines must cut off steam so late in the stroke that little or no benefit is obtained through expansion. In order to produce the best results, the engine should be just the proper size to do its work—neither too large nor too small.

It is true that there are many reasons why condensing engines cannot be generally used in Pittsburg, the principal one being the enormous amount of water required for condensation, and the cost of getting that water. The same reasons prevail generally in other cities, and there will probably be very few condensing engines used anywhere in comparison with the number of non-condensing plants. I know of instances where condensing engines are being operated, in which the water for condensation costs considerably more than the saving in fuel amounts to.

One step in the direction of economy is the introduction of the automatic- to replace the throttling-engine. The next step is the introduction of the compound- to replace the single-expansion-engine. Within the last three years, some 600 compound-engines

have been built by one Pittsburg engineering concern, and the efficiency of this engine as compared with the ordinary throttling-engine is about as two to one. This engine is available both for condensing plants and for non-condensing, just as circumstances determine. Where plenty of water is cheaply obtained, the condenser adds its own quota to the general economy, but very good results can be obtained from compounding without the condenser.

The average rolling-mill man has not up to a recent date been very exacting in his requirements as to the class of engine he will use for mill work. Usually the question of first cost has been the most important one with him. He has overlooked the fact that it costs more money to furnish steam for this cheap engine for a period of six months than its first cost amounted to. His notion seems to be that a strong shaft and a heavy fly-wheel are about all that is required. These are certainly very important items, but they are only a part of the sum total which go to make up a good engine. I think there are many of these old-time mill engines that would not run twenty-four hours if they were loaded up to a *constant* load commensurate with their cylinder diameters. The things that save them are the throttling governor and the heavy fly-wheel. The rolling-mill engine gets its work on the installment plan. A lot of energy is stored up in the fly-wheel; a piece of iron is put in the rolls and the fly-wheel then gives up part of that energy, and thus breaks the shock on the engine and helps maintain the speed until the tardy throttling governor can get into action and admit a higher steam pressure into the cylinder to meet the new conditions. After that piece of iron has passed through the rolls, the increased steam pressure brings the fly-wheel up to speed again, and the wheel by virtue of its great inertia gives the tardy governor time to reduce the steam pressure, while it prevents the engine from running away in the meantime.

Now, in electric lighting or in street railway service, the duty is much more constant and continuous, and every part of the engine must be designed for this load which never lets up as in rolling-mill service. Moreover, a variation in speed under changes of load, which variation would not be discernible in rolling-mill

work at all, might render the engine totally unsatisfactory for such service. In street railway service the load is widely variable, and is almost as erratic as in the rolling-mill; but, notwithstanding this, the engine must maintain practically a uniform speed. The old-time throttling-engine, which is so prevalent here, and so well thought of in many cases, could not be considered at all for this sort of duty and for many others, such as the weaving trades and cotton-spinning.

MR. ROBERTS: That is a very important point.

MR. BOLE: The average mill engine can often lose 20 to 25 per cent. of its speed without much complaint. The question of regulation does not seem to enter very far into this problem. The principal duty of the throttling governor in such mill engines seems to be to prevent the engine from running away.

MR. BARNES: I do not agree with you at all in that respect. The governor is the life of the rolling-mill engine. As to the work of the fly-wheel it is insignificant.

MR. BOLE: I will cite one instance where I went to a rolling-mill to find how much power was required to drive a certain train of rolls. The manager told me the engine he had was large enough to drive two such trains. I indicated the engine and found that it was doing its utmost. Every time a billet was put in the rolls, the engine slowed down fifteen to twenty revolutions out of a possible eighty per minute. If the piece of iron being rolled had been long enough, the engine would have stopped entirely.

MR. BARNES: My point was this, that with a reasonably modern automatic cut-off-engine in rolling-mill work, the governor feels the slack of the speed so instantly that the fly wheel has no time to maintain the speed independently. I doubt very much whether the fly-wheel would run two revolutions a minute with a train in some of the passes where the work is heavy. You compare the accuracy of the regulation of the rolling-mill engine with the accuracy of the electric-light engine. I do not undertake to do that. It would be absurd.

MR. ROBERTS: In rolling steel ingots they are more continuously under the rolls than in ordinary work, are they not?

MR. BOLE: I presume that depends on the activity of the plant and would vary in different mills.

At the request of Prof. Phillips, the Secretary read a resolution passed by the Board of Directors, as follows:

Resolved, Two weeks after the receipt of the last number of each volume of each magazine subscribed for by the Society, it shall be the duty of the Librarian to tie up the volume thus completed ready to be sent to the bindery, and in no case must the same be opened before sending to be bound.

There being no further business, the Society adjourned.

J. H. HARLOW,
Secretary.

NOVEMBER 17TH, 1891.

THE Society met in the parlor of the Academy at 8 P.M.

There were thirty members present, President Roberts in the chair.

The minutes of the last meeting were read and approved.

The following named gentlemen were elected to membership: R. S. D. Hartrick, C. H. Nichols, H. E. Warrington, C. H. Snyder.

It was moved by Captain A. E. Hunt that a committee be appointed by the President to nominate officers for the year 1892, which motion was carried.

It was also moved by H. J. Lewis that a committee be appointed to report on the advisability of having a banquet. This motion being carried, the President appointed on such committee H. J. Lewis, E. Swensson and A. E. Hunt.

Captain Hunt then read a paper on "Hydraulic Cements," which was discussed by Joseph Shinn and others.

HYDRAULIC CEMENTS.

THE following paper on "Hydraulic Cements" was prepared primarily as a way of instructing the inspectors of the Pittsburg Testing Laboratory regarding the qualities, manufacture, and uniform methods of testing cements.

The writer has availed himself of the data contained in a very considerable amount of literature upon the subject, scattered

through many books, and distinctly claims nothing novel in the paper, but rather would ask for favorable consideration of it from its stating in a somewhat condensed form the general facts regarding hydraulic cements as stated by standard authorities.

The methods of testing cements, as given in the report of the Committee of the American Society of Civil Engineers upon the subject, in 1886, are undoubtedly the best methods of testing cements now extant, and are fast becoming the standard and uniform methods.

From a chemical standpoint, in a general way, hydraulic cements are mixtures of caustic lime and magnesia, with from 12 to 45 per cent. of silicate of alumina. Cements have the property, when mixed with from 15 to 30 per cent. of their weight of water, of forming a thick, plastic paste, which admits of being spread or moulded like mortar made from slaked lime; and, like it, this paste sets, as it dries, to a firm, solid mass, which, when in thin layers, adheres firmly to any rough surface upon which it may have hardened; but, as distinguishing it from ordinary mortar made from slaked lime, it has the power of setting in the same way even when the mass, when partially set, is immersed in water.

The lime and silicates of alumina in hydraulic cements act very little on one another in a dry state, but, when moistened, the solvent power of the water on the lime makes it a purveyor to the silicates of alumina, causing the double reaction of the silica and alumina both upon the lime, forming, during the solidification of the cement, highly hydrated silicates and aluminates of lime at one and the same time with the hydrate of lime—these hydrates forming, after a lapse of some considerable time, exceedingly hard, compact, and strong stones; their strength depending on the crystallizing energy of the aluminates and silicates of lime. Hydraulic cements are argillaceous or siliceous accordingly as the silicates or aluminates preponderate as the acids of the hydrated cement salt.

Such cement-stones are often called "hydraulic limes." They absorb water and form the plastic paste referred to above, without the swelling of bulk or evolution of considerable amounts of heat, or the slaking and crumbling-down properties that ordinary quick-limes exhibit.

These cements are ordinarily produced by calcining varieties of limestones, called "hydraulic," containing from 10 to 35 per cent. of a peculiar form of clay—those containing the larger percentage of clay solidifying in the course of a few hours, while those containing the smaller percentages become hard only after a lapse of several weeks. Such mixtures can be prepared by intimately mixing ordinary caustic lime, or in some cases carbonate of lime, with a due proportion of clay, by grinding the two substances together to a fine powder and carefully and heavily burning the mixture. Such cements are distinguished as artificial cements in contradistinction to those prepared from the unmixed natural rock, which are called natural cements.

The Rosendale and Louisville cement localities are the two largest natural-cement making districts of the country, although natural cement is made in many localities throughout the United States.

Allentown and Egypt, in the State of Pennsylvania, are the most important places for the manufacture of Portland cement in this country.

The following tables are from the Mineral Resources of the United States for 1888:

Product of Cement from Natural Rock in the Leading Districts of the United States.

Localities.	Barrels of 300 lbs.
Rosendale, Ulster Co., N. Y.,	2,262,984
Akron, N. Y.,	715,000
Louisville, Ky.,	1,214,000
LaSalle, Ill.,	332,055
Mankato, Minn.,	160,000
Milwaukee, Wis.,	400,000
Lehigh Valley, Pa.	500,000
Potomac River,	100,000
Fort Scott, Kas.,	40,000
Howes Cave, N. Y.,	49,256
Eastern Ohio,	80,000
Onondaga, N. Y.,	250,000
Kansas City, Mo.,	50,000
Cement, Ga.,	20,000
Virginia, Texas, and New Mexico,	180,000
Total,	6,253,295

Product of Cement made from Natural Rock in the United States, from 1882 *to* 1888.

Years.	Bbls. of 300 lbs.	Average price per bbl.	Total value.
1882,	3,165,000	$1.10	$3,381,500
1883,	4,100,000	1.00	4,100,000
1884,	3,900,000	.90	3,510,000
1885,	4,000,000	.80	3,200,000
1886,	4,350,000	.85	3,607,500
1887,	6,692,774	.77½	5,186,900
1888,	6,253,295	.72½	4,533,739

Estimated Product of American Portland Cement from 1882 *to* 1888.

Years.	Bbls. of 400 lbs.	Average price per bbl.	Total value.
1882,	85,000	$2.25	$191,250
1883,	90,000	2.15	193,500
1884,	100,000	2.10	210,000
1885,	150,000	1.95	292,500
1886,	150,000	1.95	292,500
1887,	250,000	1.95	487,500
1888,	250,000	1.95	487,500

Comparative Prices per Barrel of Cement in New York, January 1, 1885 *to* 1889.

	1885.	1886.	1887.	1888.	1889.
Rosendale,	$1.00	$1.10-$1.25	$1.20-$1.25	$1.15-$1.20	$1.15-$1.20
Portland,	2.50 to $3.00	2.25- 2.50	2.00- 2.25	2.25- 2.50	2.10- 2.35
Roman,	2.75 to 3.50	2.75- 3.25	2.65- 2.85	2.65- 2.85	2.65- 2.85
Keene's com.	5.00 to 6.00	4.50- 6.00	4.50- 5.50	4.50- 5.50	4.50- 5.50
" fine,	9.50 to 10.00	9.00-10.00	7.50- 8.50	7.00- 8.25	7.00- 8.25

Rosendale cements are from the valley of the Rondout Creek, in the town of Rosendale, Ulster county, N. Y., and consist of deposits of some 30 feet in thickness of the lowest stratum of the Lower Helderberg and the upper stratum of the Niagara group of argillaceous magnesian-limestones. They are lightly burned, so as to drive off the carbonic acid from the magnesia only, leaving for the most part the more difficultly decomposing carbonate of lime still intact, only forming enough caustic lime to combine with the silica and alumina present to form complex silicates and aluminates of lime and magnesia.

The Rosendale cement was first used in 1823 in the masonry used in the construction of the Delaware and Hudson canal.

The Louisville is a similar magnesian limestone, and comes from the states of Kentucky and Indiana in the neighborhood of the Falls of the Ohio.

The following analyses are of some of the more common natural cements:

Name of Cement.	Silica (SiO_2).	Lime (CaO).	Magnesia (MgO)	Oxides of iron and alumina.	Manganese oxides.	Soda (NaHO).	Potash (KHO).	Carbonic acid, (CO_2).	Phosphoric acid (P_2O_5)	Sulphuric acid, (H_2SO_4)	Water (H_2O).
Lawrence brand Rosendale cement. made by the Rosendale Cement Co........	22.77	34.54	21.85	10.43	0.37	2.28	1.85	2.84	0.19	1.44	1.59
Louisville cement rock........	21.10	30.16	7.00	7.51	calc. sul. 6.85	0.80	0.80	25.42	....	....	......
Hoffman brand Rosendale cement made by the Lawrence Cement Co........	17.17	48.28	19.13	10.80	....	....	....	3.38	....	1.20	......
Utica cement......	35.43	33.67	20.98	9.92	....	....	....				
Utica cem't rock..	21.12	....	....	1.12	....	....	....	calc. carb. 42.25	mag. carb. 31.98	....	1.07
Akron cement rock, Erie co., New York........	33.80	....	....	4.84	....	6.18	6.18	35.60	19.26	0.50	0.14

In the most improved natural cement works abroad, and in a few works in this country, the raw rock is crushed and ground dry. The powder thus formed is run into a mixer, when a small proportion of pitch and water is added to make the mass slightly plastic. The moistened powder is then passed through a pair of heavy rolls having cavities in them, into which the mass is moulded into balls that are delivered by the rolls to carrying tables, which transport them to rotating cylindrical kilns fired by regenerative gas furnaces, where they are calcined.

The remaining operation consists in grinding and sieving the material to a proper fineness and packing for market in barrels of from 300 to 400 pounds each.

The form and size of the material, its uniform density, and the porosity occasioned by burning out the pitch allows of more even "burning" of the stone, as the calcining is technically called at the cement works, and more rapid expelling of the carbonic acid.

In the older and commoner methods, it is necessary to allow the "slurry" or ground raw stone, when formed into blocks, to remain on a drying floor for some weeks' time to dry out the moisture before calcining, which is done in vertical kilns similar to those used in burning lime.

In the various Rosendale cement works of Ulster county, N. Y., the calcining kilns are located conveniently near the quarries, and at such an elevation that the stone brought in cars from the quarries is delivered to the tops of the kilns.

The kilns are each capable of burning from 80 to 90 barrels of cement daily. They are charged and drawn twice in 24 hours. The burnt cement, after being drawn from the kilns, is conveyed by cars to the upper story of the grinding-mills, which are driven by steam-power. The mill stones are usually about 3 feet in diameter, and each pair is capable each day of grinding from 75 to 90 barrels of cement, of 300 pounds weight each, to such a fineness that less than 8 per cent. will be retained on a No. 50 sieve containing 2500 meshes to the square inch.

The irregularities in natural cements are due to:

1st. Irregularities in selecting the cement stone free from the country rock which will yield too much free lime to the cement:

2d. In neglecting to properly mix the cement stone, which varies somewhat in the different strata.

3d. From irregular working of the kilns, which causes uneven burning of the cement.

4th. Exposure to moist air of the roasted and ground cement before use.

Cement should be stored in perfectly dry rooms, having few opportunities for currents of moist air to flow through them, and on floors several feet above the ground when possible.

Undoubtedly, more homogeneous and regular results (and it

would seem as if more economical results as well) would be obtained by the more general adaptation of the regenerative gas roasting kilns in the place of the present old style vertical kilns used at most American natural cement works.

The original Portland cement was a natural carbonate of lime containing from 20 to 22 per cent. of clay, the clay itself being composed of 60 to 66 per cent. silica to 10 to 34 per cent. alumina.

Only about 5 per cent. of the total make of Portland cement at present is from this natural stone.

Portland cements are heavier than the natural cements like the Rosendale and Louisville brands, and, as a rule, set quicker.

The celebrated English Portland cements are, for the most part, artificial cements, made by grinding to an intimate mixture chalk and the clay found in the valley of the Medway, and the finely divided "slip" of "slurry" afterwards dried and carefully and very heavily burned in kilns. A high heat is required to be kept up for some time in burning in order to have the silica and alumina acted upon completely by the lime. The name "Portland" is given to these cements on account of their producing, when set, an artificial stone very closely resembling a native stone of the Island of Portland, called the Portland stone.

Generally speaking, imported Portland cement is manufactured from 60 per cent. chalk, 30 per cent. silica free from organic matter, and 10 per cent. of alumina.

Until within the last ten years, all our supply of Portland cement came from England, now we import a great deal from Germany, France, and Sweden, and quite an amount is also being made in this country.

The analyses of English, German, and American Portland cements, and of the Roman cement, are as follows: (see p. 133.)

In all important work laid in freezing weather, the best Portland cement alone should be used, using salt water to mix the cement, in the proportion of 1 pound of salt to 18 gallons of water when the temperature is at 32° Fahrenheit, and adding 3 ounces of salt for each 3° lower in temperature. In freezing weather, it is important that the sand should also be warmed to the extent of entirely taking the frost out of it.

	English Portland Cements.		German Portland Cements.		American Portland Cements.		Roman Pozzulana Cement.
	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	
Lime, CaO	59.06	55.06	62.81	57.83	60.50	58.00	8.00
Silica, SiO_2	24.07	22.92	23.22	23.81	25.50	26.75	44.50
Alumina, Al_2O_3	6.92	8.00	5.27	9.38	4.35	7.25	15.00
Ferric Oxide, Fe_2O_3	3.41	5.46	2.00	5.22	3.70	4.10	12.00
Magnesia, MgO	0.82	0.77	1.14	1.35	3.30	0.60	4.70
Potash, KHO	0.73	1.13	1.27	0.59	1.20	0.60	1.40
Soda, NaHO	0.87	1.70		0.71	0.30	0.90	4.10
Calcium Sulphate	2.85	1.75	1.30	1.11	1.15	2.10	......
Water	......	......	......	......	......	......	9.20

Experiments made by Mr. Alfred Noble, member of the American Society of Civil Engineers, shows no excessive loss in tensile strength of best quality Portland cement briquettes, either in neat cement or mixed with equal parts of sand, in an extended series of tests, where proportions of 1 ounce of salt to 35 ounces of the neat cement were used, nor in proportions of 1 ounce of the salt to 21 ounces of cement and 23 ounces of sand.

Natural cements Mr. Noble does not find stand the cold as well as artificial cements, nor do the ordinary brands of cements allow working in freezing weather satisfactorily, as does the Portland.

The original Roman cement was made by mixing lime with a volcanic tufa found at Pozzuoli, near Naples, and the cement is often called in the trade "Pozzuoli" or "Pozzulana." This Pozzulana, chemically, is a mixture of about 68 per cent. of silicate of alumina with some 6 to 10 per cent. of caustic lime and accidental impurities. Pozzulana cement requires no calcining in its manufacture, and does not have the strength of either the Portland or the American natural cement.

So-called Roman cement is prepared in England from grinding nodules of "septaria," which are found in the valley of the Thames river. It has the same general composition as the true

Roman cement, which has from 25 per cent. to 35 per cent. of clay in it, and is a very quick-setting cement.

Magnesian cements are mostly prepared in the same general way as the lime cements, by roasting the raw carbonate of lime and magnesia at such a temperature that the carbonic acid is driven off only from the magnesia, reducing it to oxide of magnesia, while the higher temperature required to drive off the carbonic acid from the carbonate of lime allows it to remain unchanged. This mixture forms a rapidly-setting hydraulic cement, which is converted into a hard, compact stone.

A compact variety of oxide of magnesium, obtained by heating the nitrate or chloride of magnesium to a temperature of bright redness, but to no higher heat, exhibits remarkable hydraulic properties. On being wet, it quickly combines with water, and is converted into a crystallized hydrate of magnesium of compact texture, harder than marble and of great durability. Pure carbonate of magnesia, when burned at a moderate intensity, ground to fine powder, and made into paste with sea-water, makes a hydraulic cement which is superior in hardness and strength to the best Portland cement.

From the report of the Committee on the Compressive Strength of Cements (*Transactions of the American Society of Civil Engineers*) is quoted below some conclusions, a part of the result of their labor.

1. Cement mortars hardening in air diminish in linear dimensions at least at end of twelve weeks, and in most cases progressively.

2. Cement mortars hardening in water increase or expand in like manner, but to a less degree, and in such a small amount in actual fact as to hardly require being considered in practical work.

3. The expansion is greatest when the increase of strength is most active and is greatest with new cement and least with that which has been kept some time in stock.

4. The contractions and expansions are greatest in neat cement mortar.

5. The changes are less in water than in air and are less in mortars containing sand.

6. The contraction or expansion is essentially the same in all directions.

7. Both Portland and Rosendale cements, when mixed neat, absorb the same amount of water as when mixed with two parts of sand and the absorption is probably least for that portion of cement that just fills the spaces between the coarser sand particles.

Mortars of cement and sand are injured by any addition of lime whatever. It is a very common error in hydraulic work to add caustic lime to cement to either cheapen it or give it better bond.

The methods of testing cements given below are the instructions to the inspectors of The Pittsburg Testing Laboratory upon the subject and follow closely the recommendations of the reports of the Committee of the American Society of Civil Engineers upon a Uniform System for Tests and on the Compressive Strength of Cements, and the papers and discussions occasioned by these reports.

General Remarks Upon Testing Cements.

I. All data regarding the history of the sample should be carefully noted. This is especially necessary where any opinion is to be given relative to the quality of the cement. This data should include how, where and when sample was obtained, and the age of the cement and amount of exposure to the atmosphere and moisture it has undergone. The facts so far as is known regarding its being a true average sample should be noted. Its color should also be noted.

II. All instructions, if there be any, as to number of tests to be made, their character, whether neat cement is to be tested; if not, what proportions of standard or other sand is to be used; whether the cement is to be sifted to any given fineness or to be tested in its original condition; time and methods of immersion; and all or any other special instructions regarding the tests should be accurately carried out so far as practicable, and all of such data should be clearly expressed upon the report.

III. The Committee upon Uniform Methods of Tests of Cement of the American Society of Civil Engineers recommends that tests of hydraulic cement be confined to methods for determining the

fineness, liability of cracking or blowing and the *tensile strength;* and for the latter, for tests of seven days and upwards; that a mixture of one part of cement to one part of standard sand for natural cements, and three parts of sand to one of Portland cements, be used, in addition to trials of the neat cement. The quantities used in the mixture to be determined by weight.

The Pittsburg Testing Laboratory follows this rule unless especially instructed to the contrary, and unless contradictory to the special instructions referred to above as coming with each sample. The inspectors charged with tests of cements regularly take the following procedure in making tests of cements:

Sampling.

Where the inspectors are required to obtain the samples, they will take four pounds of the cement and in general will obtain one such sample from every fifth barrel of the cement to be inspected; taking care in selecting the sample that it comes from the interior of the package. They will store the samples in tight fitting tin cases especially designed for the purpose and properly marked. This sample will be sufficient to make a duplicate test of a nest of five briquettes each, should it be desired. This amount of sample (4 pounds) will be obtained in all cases except where especially instructed differently. In some cases it will be desirable to obtain a test of one briquette from each barrel. In such cases 8 ounces will be all that is absolutely necessary; but it is, however, better to obtain one pound of each sample.

The amount of material needed for making five briquettes of the standard size recommended is, for the neat cements, about one and three-quarter pounds; and for those with sand, in the proportion of three parts sand to one of cement, about one and one-quarter pounds of sand and six and two-thirds ounces of cement.

Fineness.

A weighed portion of the cement sample will be sifted through a No. 50 sieve having 2500 meshes to the inch, wire of No. 35 Stubs's gauge; the coarser residue left on the sieve to be weighed. It should be less than 10 per cent. of the whole, with good cement;

and all of these particles should go through a No. 25 sieve of 625 meshes to the inch. This percentage of fineness (through a No. 50 sieve) should be reported. In some cases where the tests are for the guidance of the cement manufacturer it will be advisable to report the fineness also through a No. 74 sieve of 5476 meshes to the square inch, with No. 37 Stubs's wire; and through a No. 100 of 10,000 meshes to the square inch, No. 40 Stubs's wire; although this need not be done in regular practice.

In general, the cement will be tested in the condition it is offered for sale, and not upon sifted samples.

As data for the manufacturer or owner of a large amount of cement, as to its improved qualities, testing it for tensile strength, color, checking, etc., after being sifted, will give useful results. Care, however, should always be taken to prominently state upon the report of such results the changed condition of the fineness of the sample. The finer the cement, if otherwise good, the larger dose of sand it will take without weakening the strength of the mortar, and the greater the value of the cement.

Mixing and Moulding Sample Briquettes for Tensile Tests, Cubes and other Shapes.

Fresh, clean water of a temperature of between 60 and 70 degrees Fahrenheit should be used for the water of mixture and immersion of the samples; the proportion of water varying with the age, fineness, temperature and other conditions. The object is to produce the plasticity of rather stiff plasterers' mortar. In most cements, the amount of water actually combining in hydration in the set cement is only about 11 per cent. of the total weight, and, in general, it may be stated that no more water should be added than is actually needed to make the mass stiffly but thoroughly plastic throughout. Experience has shown the approximate amount of water required to be about as follows:

	Per cent. of water usually required of the Total weight.
For briquettes of neat Portland cement,	25
" of natural "	30
Of 1 part cement and 1 part sand,	15
" 1 " 3 "	12

If sand is added it should be thoroughly mixed with the cement before adding water to the mass.

In tests of hydraulic cements the standard sand must be homogeneous in size and shape of its grains. This is absolutely essential for comparative and uniform results. For this purpose the Committee of the American Society on Standard Methods of Testing Cements has recommended the use of crushed quartz, which shall be of such a fineness that it will all pass through a No. 20 sieve of 400 meshes to the square inch, wire of No. 23 Stubs's gauge, and all caught on a No. 30 sieve of 900 meshes to the square inch, wire of No. 31 Stubs's gauge.

This standard sand is used by the Pittsburg Testing Laboratory in all cement testing requiring the use of sand, and as it is difficult to procure this, with some of the other standard materials, by those having occasion to make cement-tests, it may not be amiss here to say that the Pittsburg Testing Laboratory keep the standard crushed quartz sand of the prescribed fineness on hand, by the barrel, as well as the standard Nos. 20, 30, and 50 brass wirecloth sieves, and aluminum mixing-troughs, and briquette and 2-inch cube moulds, to be referred to later on, for sale. It may be said, in this connection, that the irregularity of tensile tests with sand, show the importance, in regular work, of selecting clean, coarse, sharp sand, free from loam and all earthy matter, to mix with cement. Fine water-worn grains of sand will produce weak mortar with the best of cements.

The treatment with water should be done upon a slab of marble, glass, or other impenetrable substance. We have found a $\frac{1}{4}$ inch thick plate of smooth aluminum 24 inches long by 18 inches wide, slightly dished toward the center and flanged up for an inch at the edges, to prove especially advantageous for the purpose, being light and easily cleaned.

The mixing with water should be rapidly and thoroughly done by making at first a hollowed-out, dish-shaped center of the dry cement-mass upon the marble, glass, aluminum, or other slab, and pouring the water into it; then, with the aid of a trowel, mixing the mass together, when it is formed up into a central mound on the slab, and the temperature taken with a thermometer. This tem-

perature should be noted upon the report of the tests. With good quality cements this increase of temperature should not be over 10 degrees Fahrenheit for the slow-setting natural cements, but an increase of 40 to 50 degrees is sometimes noted with good brands of quick-setting Portland cements without showing signs of blowing or cracking.

Water used largely in excess, making a very thin mortar, weakens the cement, and will give irregular and unsatisfactory results in cement-testing.

Dry mixtures of a cement, using only the water absolutely needed for water of hydration of the lime and magnesia in the cement, will give higher results than the stiff plastic mortar, for the first few weeks', or even months' test, but does not give as good results after a few months' time being allowed for setting.

The stiff, plastic mortar is universally used for test purposes.

The rapidity with which a cement sets, or loses its plasticity, furnishes no indication of its ultimate strength. It simply shows its initial hydraulic activity, the quick-setting varieties of cement setting in less than one-half hour, the slow-setting requiring more time. Most of the natural cements are slower-setting than the artificial Portland cements.

The time taken for setting should be noted in making an examination of cement as to its general character.

As soon as the mortar has been thoroughly mixed and its temperature taken, it should be then, without loss of time, firmly pressed into the moulds with a trowel, without ramming, and struck off level; the moulds in each instance, while being charged or manipulated, being placed on a slab of glass, or marble, or other non-absorbent, hard, smooth, and flat surface.

The moulding must be completed before incipient setting commences. As soon as the briquettes are hard enough to bear it, they should be pressed out from the mould by aid of a wooden plunger, which should be made so that the pressure will be equally distributed over the entire surface of the briquette in pressing it out; or, better, as in our own laboratory practice hinged moulds are used for tensile-test briquettes, which more certainly prevents the liability of their being injured and less liability of the samples breaking with incorrect and irregular results, due to cross strains.

The shape of the briquette used in tensile tests is the form recommended by the Committee of the American Society of Civil Engineers upon "Uniform Methods of Tests of Cement," the section provided to be broken being calculated to be as near to 1 square inch as possible.

Five or six briquettes are moulded at a time. The metal used in the frame of the moulds is aluminum, which can be readily cast into the shapes desired and easily fitted, and has the advantages of lightness and non-corrodibility of the water and cement-mixture used.

Care should be taken that the mortar has sufficiently set in the moulds before releasing them. Should the cement settle afterwards in setting, it is liable to cause injurious cross-strains and further to produce unsound test-specimens.

Briquettes having mechanical defects in their construction or an unevenness of form should be rejected, as their results will only prove misleading.

As soon as the briquettes, after moulding, are hard enough, a space of from 30 to 60 minutes usually with natural cements and perhaps half that time with some of the Portland cements; they should be taken from the moulds and kept covered with a damp cloth until they are immersed.

In all tests except the one-day tests the tensile-test briquettes should be kept thus wrapped up in a damp cloth for 24 hours in air and then immersed.

In the case of one-day tests the briquettes should be immersed in one hour after moulding, except in the case of very slow-setting cements, which sometimes require further time to prevent their being washed away.

For tensile test, 5 briquettes should be broken and their average taken, only those being counted which break evenly in the smallest section. Any specimens showing by their breaking the influence of cross-strains, defective places, or lack of uniformity, should be rejected.

The briquettes should always be broken immediately after being taken out of the water and dried and measured for section, the testing-room having a temperature of between 60 and 70 degrees

Fahrenheit, if practicable; if not, the temperature should be noted upon the reports.

It has been the writer's experience that specimens pulled at very low temperatures show less tensile strength than normal results obtained between 60 and 70 degrees Fahrenheit.

The stress should be applied to each briquette at a uniform rate of about 400 pounds per minute, starting each time at no pressure.

With a very weak mixture, showing less than 30 pounds per square inch, a speed of 200 pounds per minute should be used.

To have the speed with which the stress is applied uniform is of great importance. Henry Faija, in an article read before the Institution of Civil Engineers, in 1884 (*Proceedings of the Institution of Civil Engineers*, vol. lxxv., p. 225), gave the results of several hundred experiments by applying the strain at different rates of speed, as follows:

Strain and speed.	Specimen ruptured at.
100 pounds in 120 seconds.	400 pounds per square inch.
100 " 60 "	415 " "
100 " 30 "	430 " "
100 " 15 "	450 " "
100 " 1 "	493 " "

As the specimens were uniform in character and the results given were carefully-prepared averages of many tests by a skilled experimenter, it is proved that an increase of nearly 25 per cent. in strength is obtained by adopting the quick speed over the slower one. I may say here that my own experience verifies these results, and that it is of the utmost importance, for uniform comparative results, to use a uniform speed—that of 400 pounds per minute as recommended by the American Society of Civil Engineers' Committee, having been adopted not only on account of its being more generally used, but also on account of its giving more uniform results than the quicker speeds.

Time of Setting. Checking or Cracking caused by too great an Expansion or Contraction; and Color.

Three cakes of each sample to be tested, should be made of neat cement made into a stiff paste mortar, and moulded into cakes about two inches in diameter and one-half inch thick, with

thin edges. With one cake, note the time taken for the cement to set hard enough to stand the load of a No. 14 Stubs's gauge wire loaded with one-quarter of a pound, and of a No. 19 Stubs's gauge wire loaded with one pound. One of these cakes should, when hard enough, be put into water and examined from day to day, to note if it becomes distorted, and if cracks show themselves on the edges. Such cracks indicate a poor quality of cement. Sometimes trouble is occasioned by the presence of too much unslaked lime, a trouble which disappears with age. A second cake can be more speedily tested for cracking by keeping it in hot moist air for some six hours at 100 degrees Fahrenheit, and then immersing in water at about 110 degrees Fahrenheit for eighteen hours more, when, if it is liable to crack at all, the trouble will develop itself. The remaining cake should be tested for color, keeping it in the air, and noting its color, which should be uniform throughout in good cement, yellowish blotches indicating a poor quality. The Portland cements have a bluish-gray color, the natural cements having a light or dark color according to the character of rock of which they are made. The indications given by the color as to the character of cement, are much better when it is left in the air, than when the placques are left in the water for a time.

Time and Treatment.	American Natural Cement, Neat: Pounds per sq. inch.	American and Foreign Portland Cement, Neat: Pounds per sq. inch.	American Natural Cement, 1 part Cement, 1 " Sand: Pounds per sq. inch.	American and Foreign Portland Cements. 1 part Cement. 3 parts Sand. Pounds pr. sq. inch.
24 hours. One hour in air; remainder in water.	40 to 80	100 to 140	....	....
One week. One day in air; six days in water.	60 to 100	250 to 550	30 to 50	80 to 125
One month of 28 days. One day in air; 27 days in water.	100 to 150	350 to 700	50 to 80	100 to 200
One year. One day in air; the remainder in water.	300 to 400	450 to 800	200 to 300	200 to 350

The foregoing table, prepared by the Committee of the American Society of Civil Engineers' on Uniform Methods of Testing Cements, from their researches and experience, shows the average maximum and minimum tensile strength per square inch, which good cements have attained when tested under the conditions recommended by the Committee, which are practically those described and called for in this paper.

It will be safe for any engineer requiring first quality cement to insert a requirement for the minimum strength reported in this table in his specifications.

A requirement often called for in English specifications for first quality Portland cement is 176 pounds strain to be successfully withstood without fracture at the expiration of three days from moulding, and an increase of at least 50 per cent. over the three days' test at the expiration of seven days, with a further provision that at the end of seven days, the minimum tensile strength per square inch shall be 350 pounds. The value of the tensile test within six months, or with some cements, even a year's actual trial, can only be determined by comparing the increase of strength between two dates; the usual comparison being between the three days' and the seven days' test in England, and between the one day and the seven day test in America; especially where testing our slow setting natural cements, the three day test is often also used in the comparison.

In general, it may be claimed that the greater the increase in strength between the two dates, the longer it may be expected that the cement will increase in strength, and the greater the ultimate strength that will be obtained.

Quick setting cements, having large hydraulic activity, like most of the Portland cements, usually obtain their greatest strength in about six months' time, while many of our American natural cements take at least double that time to gain their maximum hydraulic strength. Hydraulic activity referring to the time required to attain a small degree of strength and hydraulic strength or energy to the ultimate strength obtained after lapse of considerable time.

The test with weighted wire referred to above, gives the hy-

draulic activity of a cement; the tensile test after a year's time, giving a measure of the hydraulic strength.

Comparative tensile tests of different aged samples, if properly made, and the results properly interpreted from the conditions under which they are made, are a good indication of the value of the cement. But the results should be considered carefully and with judgment before generalizing upon them. For instance, a very high tensile strength at an early date indicates a cement verging on unsoundness from its injurious cracking and checking, and a very slow setting cement which for certain purposes, where it is to be laid above water, may develop into a very strong cement after it has finally set, and it may be a decided advantage in the matter of mixing, and the rapidity with which the cement is required to be used, to have the slower setting cement showing comparatively weak result in the twenty-four hour test.

A single one day's tensile test of a new and untried brand of cement, however satisfactory is the result, is an unsafe guide to go by; and it would be far safer to use a trustworthy brand without applying any tests, whatever, than to accept a new article which has been tested only for one day. For while the best accepted brands require careful testing to insure uniformly good cement, the risks will be ordinarily far less in such a case than in the interpretation of a single day's test of an unknown brand.

Other Tests of Cements.

Specific gravity tests of cement or the weight per cubic foot have proved of doubtful utility, and seem to be, with our present knowledge, unnecessary.

The *adhesive test* of cement, so far as the methods for determining it have been devised, is a variable and uncertain one, as the results depend very largely on influences external to the character of the cement itself.

Where the *compressive strength* is required, one inch cube samples can be conveniently prepared by grinding and rubbing the ends of the broken tensile briquettes. It is, however, the best practice to use two inch cubes for compression, and to use hinged moulds producing cubes a little larger than two inches to allow

rubbing to a smooth surface and even bearing, with truly right-angled corners. Such test specimens can be readily crushed in the ordinary forms of metal testing machines, such as the well known makes of Olsen, Riehlé or Emery.

Great care should be taken in making crushing tests of cement cubes, that the faces are ground very smooth to insure even bearing, and that all of the angles of the cubes are exactly 90 degrees, to insure direct compressive strains only.

Weight.

For any particular cement, the weight varies with the degree of heat used in burning, the degree of fineness in grinding, and the density of packing. Other things being equal, the harder-burned varieties are the heavier.

The difference in weight for any particular kind is mainly due to a difference in fineness.

	Pounds per Cubic foot.
Portland, English, and German,	77 to 90
Portland, fine ground French,	69
Portland, American,	95
Roman,	54
Rosendale,	49 to 56
Lime of Teil,	50

Reckoning a bushel as 1.244 cubic feet, the weight of a bushel can be obtained sufficiently close by adding 25 per cent. to the above figures.

Handling and Using Cements in Actual Practice.—Cement should never be mixed with sand, long before use; but should be, after thoroughly mixing, tempered with water and used without delay. The less the proportion of sand in the cement, the stronger the mortar. In work, where mortar of extraordinary strength is required, a mixture of two parts of cement and one part sharp sand will give the best results, and a mixture of more than two parts of sand, and one of natural cement in mortar is not advisable, but with Portland cement, one part of the cement can be safely mixed with three parts of sand, in ordinary work. The mortar should be mixed on timber platforms whose

dimensions and number are controlled by the character and size of the work; the ordinary dimension of the mortar beds being about 10 x 12 feet. A proper quantity of sand is spread in a thin and uniform layer over the platform; the cement being then put on in the correct proportions in a layer on top of the sand, both being then thoroughly mixed, dry, and spread out uniformly, when the proper quantity of clean water should be poured over the mixture and the mass then thoroughly mixed. Nothing is gained by allowing cement mortar to stand for any length of time undisturbed after mixing; the sooner it is used the better.

The mortar should be conveyed from where it is mixed to the place where it is to be used, in hods or boxes, and should not be pitched from shovels or dumped through spouts from any heighth, as this is liable to cause the separation of the sand from the cement.

For concrete, one barrel of cement with two barrels of sand for every four barrels of broken stone give the best results. In all mixtures of concrete, it is necessary to fill the interstices between the crushed stone with mortar. This should be done by tamping the mixture well.

The practice of making grout by simply thinning common cement mortar with water, is a very bad one, as the water retards the crystallization long enough to allow the sand and cement to separate; the sand going to the bottom. Grout should always be made with neat cement, and should be reduced with water to the proper consistency, so that it will thoroughly permeate and fill all the voids in the concrete.

In laying brick work with cement, it is very important in dry weather that the brick should be wet before the cement is laid, else the dry brick will absorb the moisture from the cement before it is set, and prevent the formation of the hydrated silicates necessary for forming the cement bond. Neglect in this matter has caused very bad results.

The following may prove convenient for reference.

1 cubic foot of neat cement produces about .8 cubic feet of mortar.

1 cubic foot neat cement, and 1 cubic foot of sand, produce 1.4 cubic feet of mortar.

1 cubic foot neat cement, and 2 cubic feet of sand, produce 2 cubic feet of mortar.

1 cubic foot neat cement, and 3 cubic feet of sand, produce 2.6 cubic feet of mortar.

2 cubic feet neat cement, and 1 cubic foot of sand, produce 2.2 cubic feet of mortar.

Discussion.

Mr. Wilkins: In connection with Captain Hunt's paper I would like to read a couple of paragraphs of a paper read before the Engineers' Club of Philadelphia:

"In the purchase of cement for this work, an important step has been made in what is practically a new method of purchasing cement in this country. Specifications covering the usual requirements for fineness, freedom from lime, checking and tensile strain, neat, with two parts sand, and with three parts sand, were sent out to a number of bidders. In these specifications the fineness to be guaranteed was left in blank, the time of setting was left in blank, and the tensile strain, neat, with two parts sand, and with three parts sand, was likewise left in blank. These blanks were then filled up by the several manufacturers, each one guaranteeing what he would sell for a given price. It then became a very easy matter for the engineer, Mr. Clemens Herschel, the well-known hydraulic expert, to determine, by comparison with the specifications of the American Society of Civil Engineers for cement neat and in various sand mixtures, which of the several cements was cheapest per yard of cement mortar of the desired strength for his work, taking into consideration the price bid for the cement, the cost of his sand, and the guaranteed strain for mortar with two parts of sand and for three parts of sand.

"In the case in question the contract was awarded to the 'Improved Union' cement made by the American Cement Company, Egypt, Lehigh county, Pennsylvania, upon a guarantee that the three to one mortar would give as high a tensile strain as the two to one mortar offered by the average Rosendale manufacturer; and the result of the work has more than justified the experiment, as regards both quality and cost, as the average tests for the two

years that the work has been in progress show that the specifications have been on the average exceeded by more than 50 per cent., and that in point of fact, with a cement not a Portland, and which is produced by the intermixture of Portland cement and natural cement, results have been achieved which are at long periods almost equivalent to the results obtained by Portland cements."

Captain Hunt's article, on page 16, says the most trouble is occasioned by the presence of unslaked lime, a trouble which disappears with age. I had an experience which proved the truth of that some years ago. The cement which was used in the construction of the Brinton Bridge on the Pennsylvania Railroad over Turtle Creek was tested. We tested ten barrels out of each car. One car came, in which the first test we made showed only 12 pounds to the square inch on the 24-hour test. I told the contractor he might as well ship that car back. For some reason or other that car laid around the yard about two weeks. He said to me one day, "I wish you would test that again?" I did test it again, and it went up to 30 pounds. In about two weeks we tested it again, and it tested over 60 pounds. I told him I guess that lot could stay. There was considerable unslaked lime which became slaked by the car standing for this time.

Mr. Hunt: What do you mean by the word "slaked?" What is the action in the slaking of that lime?

Mr. Wilkins: The chemical action.

Mr. Hunt: The real action. My own idea is, that it is the action of the carbonic acid in the atmosphere upon the oxide of lime in the presence of a certain amount of moisture, but not a large excess of moisture; that it is the carbonate or hydrate of lime, in which hydration is not very excessive; that is the difference between the air-slaked lime and one where it is slaked rapidly by the excess of water.

Mr. Wilkins: Don't you think it is a mistake of most engineers to say in their specifications that the cement shall be freshly burned and ground?

Mr. Hunt: I think that is a very great mistake. I should rather use one that is set for some time, provided it shall have been kept thoroughly dried.

Mr. Wilkins: The government specifications almost all contain the clause that all cements shall be freshly burned and ground.

Mr. Hunt: The idea of my suggestion is, that if set for any length of time and it suffered from moisture, it would have caused the hydrates to already form in the cement, and it would be weaker thereby.

Mr. Wilkins: I have read in some place that the custom on large work in England is to have the cement used piled on a half dozen different floors made of slats which they can turn. The cement is unloaded on the top floor and tested when it reaches the bottom floor, so that by the time the cement is used it is all air-slaked.

Mr. Hunt: I will just say a word there. It is the same principle with reference to the use of lime. We make a great mistake in this country to use our limes as fresh as we do in mortars without giving the lime sufficient opportunity to air-slake. It will give more strength and a better mixture if we adopt the custom in use abroad of letting the lime slake for at least three months before use. There it is almost required by the building laws, I think it is required, that it shall be slaked for at least three months' time.

A Member: Is that without quenching first?

Mr. Hunt: Yes, I understand so.

Mr. Roberts: You refer to the use of two pounds of salt to a barrel of water, or a pound to eighteen gallons. Does that salt have any injurious effect in peculiar situations, in the walls, for instance, afterwards creating dampness?

Mr. Hunt: I do not think it would. The salt is recommended for use, during low temperatures, in heavy foundations; not in finished buildings, which should never be built in freezing weather. In piers and abutments of bridges, and works of that class, it is especially adaptable.

Mr. Noble, in a paper read before the American Society of Civil Engineers, has shown that the strength of cement is not injured by the addition of salt, and the presence of the salt prevents the freezing of the mixture, and, in that way, preventing the hydrated silicates and carbonates which form the body of the stone from

complete action. If you alternately freeze and warm the fresh mortar, you destroy this formation of the cement stone.

Mr. Wilkins: Have you ever had any practical experience with cement swelling indefinitely?

Mr. Hunt: I have had no definite experience to which I could refer just now, but I do believe there are some cements which do keep on swelling for some time beyond the initial action. I have heard of some wonderful things in that line, but I have not seen them in my experience.

Mr. Jos. A. Shinn: Being in Captain Hunt's office a few days ago, he referred to the paper that he was about to present to this society on the subject of cement. I made a remark in his presence which prompted him to invite me here this evening. I have taken a great deal of interest in this subject, having been actively engaged in the manufacture of lime and cement for seven or eight years, and having devoted the greater part of two years, in addition, to experimental work on both cements and lime mortars.

I do not know of any material that is so generally used by the civilized nations of the world, and which has been used for so long a period, of which there is less accurate knowledge than that of limes, cements, and the mortars made from them. And yet, almost every child in civilized countries knows, in a general way, how to make lime mortar. The custom in this country, or largely so, is to put the most ignorant man on the job in charge of the mortar-bed and the mixing. That is not always absolutely bad, because, if he acts as a machine, and is properly instructed, he will make good mortar; but, as it is frequently trusted to his own judgment, and to the demands of the mason for whom he is mixing the mortar, he gets the very worst average results, in my estimation.

At the time of the late accident at Park Place, the cause was attributed, for a time, to the poor quality of the mortar used in the construction of the building. It may have had something to do with that accident. Reference was also made to the so-called "Buidensieck" disaster of a number of years ago as an evidence of the use of poor mortar in the construction of large buildings. The facts as I found them, in New York city, were, that the mor-

tar generally used was not cheapened by the using of loamy sand, but that it was made weak by using an excess of high-priced white lime. The white lime is used in preference to the brown, because it gives a greater volume of paste, and is therefore cheaper than the brown per cubic yard of mortar made to conform to the requirements of the mason. Masons doing work by measurement or count, require a smooth, easy-working mortar, which, when made with sharp sand, requires an excess of lime. This is largely the cause of the weakness of the mortar used.

The same is true of plaster, to a great extent. In my opinion a better mortar could be made, using loamy sand in order to get the smoothness, and with brown lime, using a less quantity of lime, than can be made with sharp sand and an excess of white lime; and my experiments, covering about eight months in New York, fully sustain this opinion.

I got mortars from a number of buildings, taking care to get them just as they were to be delivered to the mason for use, just previous to being shovelled into the hod, and I found that the average for cellar stone-work was about twelve pounds at twenty-eight days; for brick-work, the average was about fifteen pounds. If the mortars had been mixed with the proper quantity of lime, thoroughly mixed, they should have given about twenty to twenty-two pounds. I got that result, pretty uniformly, using as nearly the same lime as I could get to compare with it.

As Captain Hunt stated awhile ago, the custom in Europe is, largely, to require lime to be slaked not less than three months before being used. It is slaked in large pits prepared for the purpose, usually over winter, and it gets thoroughly slaked and hydrated. It is then mixed by machinery, and gets a thorough mixing. As labor is cheaper there, and they pay more attention to getting good results, they do not give it an excess of lime, and they get a good strong mortar; I presume up to as high as thirty pounds to the square inch.

As to the cements, there is more known; a great deal more known now in this country, than there was in Europe ten years ago. Previous to fifteen years ago, there was very little practical knowledge as to the strength of cements in this country. There

had been no efforts to test cements in practical use, except in a few instances, such as hydraulic work in New York, and a little, possibly, in Government work, and cement was made at haphazard.

Mr. Hunt states in his paper, that Portland cements are quicker setting than the native. That is probably true at the present time, but I can say, pretty positively, that previous, to say 1876, that was not the case. Our native cements were quick-setting cements, when they were of average good quality. When they were slow-setting cements, they were little better than brown lime, but after the introduction of Portland cements, the start of which in this country only dates back as far as 1873 (at that time I think there were less than 70,000 barrels imported, but it has increased very rapidly since), there was very little cement-testing done, very few specifications; but when the engineers got to using the Portland cements, the expense of it, at that time $5 per barrel in carloads, f. o. b., New York, required them to adopt tests, and that led to the testing of natural cements. That caused the cement-makers to produce a cement to conform to certain tests. Before that time, cement was sold that would set in five minutes. It was almost impossible to use it. I have known of Louisville cement, that it was almost impossible for masons to use on a job. They devised means of retarding the setting of the cement. How they did that I do not know. I should say, probably, either by a less degree of burning, thereby developing less free lime, or it was by a greater degree of burning to destroy, to some extent, the formation of silicate of magnesia. Either one might have that action, but they were compelled to produce a cement more nearly like the Portland.

Now, the question arises, have they improved their cement in a general way by so doing? Have they got a stronger cement today than at that time? Or, have they sacrificed strength to get qualities which could be judged of without testing? That is to say, the buyer would conclude it was good cement because slow-setting, and because Portland cement had that quality. That is what I think accounts for the native cements now setting slower than the Portland. There is very little Portland cement made in

this country. I do not know but one works here, and would like to ask Mr. Hunt where the works are to which he refers?

Mr. Hunt: Egypt, Pennsylvania, near Allentown. It is made by the same method of manufacture as abroad.

Mr. Shinn: I do not know of but one works that was making true artificial Portland cement. It began operations in 1876, at Wampum, and has been producing cement continuously ever since. The Portland cement made at Allentown is made from a natural cement rock, formerly used for making a natural cement of low strength, by light burning, but which was found to contain, unevenly distributed, the elements of true Portland cement, and that by grinding the stone raw and mixing it in its powdered state, they brought the several ingredients into intimate connection, and by heavy burning they produced Portland cement. It is liable, I think, to considerable variation, because they were working in a quarry of a strata more than 100 feet in thickness exposed, and those strata varied considerably in their chemical constitution.

Another instance of which I have knowledge is the Buffalo-Portland cement which was made as a natural cement for a great many years. They found that one of the strata in their quarry would produce a very fair imitation of Portland cement, and a very much better cement than the average of the common cements, by the assortment and a little different treatment of burning. Whether the taking of that strata reduced their native cement in value, or whether this stone required different treatment and had adulterated the other portion, I cannot say, but it certainly did one or the other.

There are several contradictions in the matter of limes and cements. White lime, air-slaked, or slaked in any way, produces a large volume of lime paste. The brown limes, containing as they do 92 per cent. of carbonate of lime and 8 per cent. of silicated alumina, and oxide of iron, swell very little in slaking, and it would be reasonable to suppose that as you went down in the scale in carbonate of lime, the volume of paste would continue to decrease and the lime slake with less energy, but in Portland cement, with a mixture containing possibly 64 per cent. of lime, 24 per cent. of

silica, and 12 per cent. of alumina, it was found that if the percentages varied to the extent of 1 per cent. increase of clay, it caused a very rapid slaking with a very considerable increase in bulk, and it is not to be accounted for on the same theory as the slaking of lime.

Then, going to the natural cements which contain still more of the clay mixture, they do not slake at all in the air; that is, ordinarily. They will eventually, I suppose, but not to any degree to interfere with their manufacture. So there are inconsistencies which must be explained by a more thorough examination of the subject than has yet been made. The question of why an air-slaked lime will not set, will not make a good mortar, has not been fully explained to my satisfaction, and if the lime mortar hardens only by becoming a carbonate, why does it not harden when covered by water, water being the best conductor of carbonic acid, as in the case of hydraulic cement?

It has been claimed by a great many writers that lime mortar becomes a silicate of lime. I do not believe there is a particle of silicate of lime in the oldest lime mortar. It is simply the nucleus of a grain of sand surrounded by a thin film of lime, which becomes a carbonate of lime. Its action, forming around a core of that sort, is very much like the forming of nodules of iron-ore around the sandstone.

It has been claimed by many that the ancients knew more about the use of limes than we do, and in that connection it has been stated, I do not know whether on the basis of chemical examination or not, that the pyramids were made of a mixture of something similar to Portland cement. I do not believe that the ancients knew any more about such things than we do, or had better facilities, but they had plenty of cheap labor. When they did work, they did it thoroughly. Their mixing of the mortar was thorough. In this country one man must do the mixing, if it is a very large job; and if it is more than he can handle properly, he mixes it improperly. That is the whole secret.

In some experiments in New York I got some very remarkable results. I mixed 10 per cent. of common brown lime, with 90 per cent. of material, which may be termed "inert" material.

I got a tensile strength of 140 pounds in 28 days, and that mortar could be delivered to the building in New York at a cost not to exceed that of lime and sand mortar, which gives, as I said, 12 or 15 pounds to the square inch in 28 days. But the law of New York State says that mortar shall be made of sharp sand and lime. If any man made it of anything else, particularly if it happened to be cheaper, the newspaper writers, the officers of the law, the building inspectors, would be after him. They do not get after the man who uses poor material, they get after the man who uses a good one.

The making of mortar is to be carried on as a business. They have started it in Washington City and also in New York City. They mix the mortar and deliver it as other manufactured articles are delivered, the mortar being made by machinery and guaranteed as to certain qualities, required for different uses.

Mr. Hunt: I would like to add further upon the subject of testing cements from articles lately published on the subject since my paper was written, as follows:

1. A good criticism upon the rules for testing cement, of the American Society of Civil Engineers' Committee, given in my paper, is that they fail to determine the exact degree of plasticity of the mortar to be used in the fabrication of test specimens, and also the absolute pressure to be used in moulding them.

2. Mr. D. J. Whittemore calls attention to the fact that tests of different sizes of specimens of the same mortar give results for tensile strength per square inch varying approximately in an inverse ratio to the periphery of the breaking section; that is to say, that a briquette with a breaking section of one and one-half inches square indicating a tensile strength of 40 pounds per square inch, when similarly tested in briquettes having a breaking area of one inch square, will show a strength approximately of 60 pounds.

3. With careful work of a skilled cement tester, the average differences in retesting the same homogeneous cement for tensile strength do not exceed 5 per cent.

4. The resistance of mortars of Portland cements to compression increases for from seven to twenty-eight days more rapidly than its tensile strength; at twenty-eight days it is about nine times as strong.

5. Mr. Alfred P. Boller gives the results of compression tests of cements used in the foundations of the 155th street viaduct for

	Neat.			Mortar, 1 sand, 1 cement.		Mortar, 3 sand, 1 cement.	Mortar, 5 sand, 1 cement.	
	7 days.	3 months.	1 year.	4 months.	1 year.	4 months.	4 months.	1 year.
Experiments 1 and 2......	399	526	728	415	715	186		
" 3 and 4......	540	654	692					
" 5 and 6......	....	....	....	....	....	....	152	189

the city of New York. All the blocks, except No. 6, were broken at right angles to the planes of ramming and crushing, surfaces were smoothed and made true with plaster of Paris, the cement being the Alsen brand, having an average tensile strength of 450 pounds per square inch in seven-day tests.

6. Mr. Alden H. Brown has published in the *Engineering News* of November 21st, 1891, an interesting article with instructive plates upon the testing of the quality of cements with the microscope, which would seem to indicate that at least there is a valuable possibility yet to be developed in the method of testing cements in this way, the idea being that the character and the homogeneity of the minute grains of the cement will show its relative strength.

Society adjourned.

J. H. Harlow,
Secretary.

December 15th, 1891.

The Society met in the parlor of the Academy at 8.10 P.M. President T. P. Roberts in the chair, and thirty-two members present. R. N. Clark was elected secretary of the meeting in the absence of Mr. Harlow.

The following gentlemen were elected members by vote of the Society, the Secretary casting the ballot: B. H. Parsons, S. J. Macfarren, Cornelius Kane, Robert L. Walker. The committee appointed to nominate officers for the ensuing year reported as follows: A. E. Hunt, President; R. N. Clark, Secretary; Phineas Barnes, Vice-Secretary; A. E. Frost, Treasurer; Robert Munro and G. W. G. Ferris, Directors. The Committee on Banquet, by Mr. H. J. Lewis read the printed report of the committee, which was by motion accepted and ordered mailed to all members. The paper by Mr. E. Swensson, on "Bridge Details," was then read and discussed by the following members: W. G. Wilkins, M. J. Becker, J. A. Brashear, W. L. Scaife, H. G. Lewis, S. H. Johnston, R. N. Clark, after which it was decided that the paper be held over for future discussion.

BRIDGE DETAILS.

Introduction.

Mr. President—Gentlemen:

The object of this paper, as described to me by your Programme Committee, should be to show the improvement, compared with the past, in the present practice of detailing; but, as the limited experience of the writer does not go back very far, an attempt to cover the whole ground will not be made, but only an endeavor to show how the best detailing is done at the present day, and to give some examples of faulty detail construction in past practice.

We will dismiss from this paper the consideration of all cast-iron bridges, in whole or in part, as the very nature of cast-iron is so uncertain that the use of it for even details must, with our present knowledge of detailing, be considered faulty, with the exception, perhaps, of heavy end-shoes and chairs or blocks under shoes and stringers in place of stone blocks.

It is hoped that these few comparisons will provoke a lively and instructive discussion, and that other members will be reminded of, and give the Society the benefit of, their observations on this subject.

General.

Taking up the subject in general, I find four laws governing the construction of details which should always be borne in mind by the detailing engineer.

1. The detail, connecting a member to the rest of the structure, should always be capable of developing the full strength of the member.

2. The detail, connecting a member to the rest of the structure, should transmit the strain by the most direct route.

3. The detail, connecting a member to the rest of the structure, should transmit the strain to the body of the member gradually, by way of easy and graceful curves.

4. The detail, connecting a member to the rest of the structure, should not produce any eccentric and undue strains on any member.

These laws have been, and are always, more or less sinned against by detailing engineers, but vastly more so in the past than at the present day. It is, however, very often next to impossible to live up to the letter of all these laws, at one and the same time, on account of practical considerations, but these practical difficulties are more and more mastered by the bridge shops and engineers, when they work hand in hand and the additional expense incurred in devising means therefor is willingly borne by the customer.

In the following you will see how these general laws are sinned against and how difficult it is to always strictly adhere to them. (By the way, it is readily seen how much easier it is to detail a pin-connected than a riveted truss and come within these laws.)

Tension Member.

When transmitting the strain into tension members in pin-connected bridges, the bar-head and the loop-eye are the usual forms employed. The bar-head, according to the practice of to-day, should have an excess of material over the body of the bar of from at least 30 to 50 per cent., so as to insure the breaking of the bar in the body instead of in the head. The re-

lation of size of pin to width of bar is of great importance when determining excess of material in head, as is also its shape. If the pin is much smaller than the width of the bar, then it acts as a wedge and the head should be elongated at the back, and have a large percentage of excess; if the pin is much larger than the width of bar, then bearing comes largely into play, and the bar does not need to have such a large excess of material, but should have a long neck, so as to transmit the strain gradually, and by easy curves. If the excess of material in the head over the body of the bar is 50 per cent., and the head is concentric with the pin, and the neck has a curve, whose radius is equal to the diameter of the head, then the size of the pin should not be less than 90 per cent. of the width of the bar. Some specifications, however, permit a pin, the size of which is only 75 per cent. of the width of bar.

The above has, in the past, very often been ignored, in so much as heads have been made with very little, if any excess of material over the body of the bar; pins were usually too small for the bar, and the head was joined to the bar with hardly any neck. Especially has this been the case with heads made on round and square rods, the flattening out of bar with a trifle or no upsetting, and a pinhole, the size of which did not seem to cut any figure, being all that was deemed necessary for the connection of said rods and the development of the full strain in same.

Loop-eyes are now used on square and round rods in preference to bar heads, which are only used when the sectional area of member favor the use of flat bars.

The loop-eye, used in the present practice, is the body of the bar bent around the pin and welded together at meeting point, making length of loop from back of pinhole to weld three and one-half times diameter of pin. Of course this gives an excess of material in loop over bar of 100 per cent.

The weak point in past loop detailing is the small pinhole and short loop, which transmitted the strain into body of rod too abruptly.

Square and round bars, with loop-eyes, are mostly used for counters, laterals, and sway bracing rods, all of which should be

made adjustable by means of turnbuckles or sleeve-nuts. By the way, it is surprising to note that bridges at this very date are built with non-adjustable counters. A separate loop, welded to a nut, is sometimes used on counters instead of loop-eyes and sleeve-nuts. Forked loop-eyes are used instead of plain single loops, on laterals and sway rods, when connected to one single plate, thereby insuring double shear on pin. Instead of forked loop-eyes and sleeve-nuts, clevis-nuts are now frequently used.

Excess of material in separate loop is 100 per cent., as in the looped rod; in forked loops it is from 35 per cent. to 70 per cent. and in clevis-nuts from 50 to 100 per cent. The variation in percentage of excess in forked loops is a result of practical considerations, first of which is the fact that material is rolled to $\frac{1}{16}$-inch only; the variation in sleeve-nuts is a result of the economy, as well as the convenience, of having a limited number of dies for forging same. The principal error in past detailing, of lateral and sway-rod connections was in using plain loops at all times, whether the shear was single or double.

The tension members in riveted structures must, necessarily, have as much larger area as is cut out by the first rivets connecting the member, which, with the best arrangement, may be reduced to one rivet. An arrangement of rivets connecting tension members in such manner that more section is cut out of member than provided for, is often noticed in detailing of riveted structures.

Pins.

Truss-pins, the principal strain-transmitters in American bridges, should be made sufficiently large to take the shear, bearing and bending, from the different members connected by means of them. If large enough to sustain bearing and bending from the different members, they are always large enough for the shearing strains, and, if members are successfully packed on the pin, the bending on the same, produced by this packing, will often give a smaller pin than the bearing of any eye-bar in this packing will do. Thus the following method in finding the size of pin should be used: Find size of pin sufficient to take the bearing from the eye-bars, then reinforce the bearings of the built up members and pack all

the members on the pins, taking all other things into consideration, so as to give the smallest maximum resultant bending moment, and if that gives a smaller pin than the bearing of the eye-bars did, the size of the pin is as first determined, but if a larger pin is the result then a repacking of the members must be tried until all possibilities have been exhausted. However, as these trials are tedious, and if difference in size of pin for bearing and bending is small, it will not pay to continue the calculation too long, but use the size given by bending. In packing of eye-bars on pins the divergence of any one bar from centre-line of truss must not be greater than 1 per cent. of its length without bending of heads parallel to centre-line. In the early days of pin-connected bridges the pins, according to above theory, were invariably made too small; in fact, their diameters seem to have been simply guessed at and it is a surprise that not more of them have broken. It is presumable that the large safety factor, the close packing of members (practically reducing the theoretical lever arms and consequently the bending moment) and elasticity of material allowing the pins to bend, have been their salvation. Some of these small pins have, however, visible indentations in their surface from excessive bearing strains as well as permanent sets from bending.

The turning down of ends of pins to receive pilots, the use of which facilitates the driving of pins in erection, is a decided improvement on past practice.

End-Post and Top-Chord.

In detailing the end-post and top-chord, we are first confronted with the location of pin-centre in the same. The eccentricity is often so great that the pin-centre comes too close to the cover-plate, not leaving enough room for eye-bar heads, making it necessary to put holes in cover-plate for projection of bars, or move down the pin-centre, which, of course, will produce eccentric strains in the chord. A chord-section designed too narrow is still oftener encountered; and it will greatly tax the ingenuity of the detailing engineer to get in all the members supposed to be packed inside the webs. The hip-joint, especially, is a troublesome point in

this respect, if the suspender at that point is a stiff riveted member, as the reinforcement of pin-bearing here is greatest, and, even if it would be good practice to put all or nearly all the reinforcement on the outside of web, it would interfere with the rivets in top flange. The above are difficulties met with in small spans in particular and has in the past led to many insufficiently reinforced bearings at the hip.

Rules 2 and 3 have in the past, as well as very often at the present day, been sinned against when determining width and length of bearing-plates. These plates should be of sufficient width to take hold of rivets through the flange-angles instead of, as is often seen, only wide enough to go between the angles and merely connect to the web. These plates should also be long enough to permit the strain to go into the flanges gradually and by an easy curve. This point is ignored, mostly in large spans, where the permissible width of plates is so great as to admit of the necessary number of rivets in very short lengths of said plates.

One of the pin-plates should extend at least three inches beyond the edge of the tie-plate. Of course all the above refers to hip-joints with only pin-bearing or open joint as, if joint is closed, the reinforcement of pin-bearing need not be so thick and consequently give more room for packing. It is not safe, however, nor good practice, to count on anything but pin-bearing, even if joint is theoretically a closed one, as it is next to impossible to have it perfectly closed at the time when it should be. The open hip-joint is also greatly preferable because it facilitates the erection.

The jaw or check-plate is a valuable addition to the hip-joint adopted by later years' practice, in preventing displacement, caused by sudden jars, or shocks, of post and chord from their relative positions on pins, as well as being of use in erection. These jaw-plates should be put both on the chord and post, inside on the one and outside on the other; of course, they may be counted as part of bearing.

A cap-plate is nowadays generally used to cover up top of joint, as well as splice-bars on bottom flange at this point.

All the above remarks are also applicable to the break-points in broken chords. Straight chord-joints, which are now usually

kept off the pin-centres, but made as near as possible to pin and on side towards ends of bridge, are detailed for transmission of strains by bearing only, and are simply spliced sufficiently to hold the parts firmly together. This rule is, however, very elastic and splices are often found that are rather weak to take care of any severe shocks which may come upon them. Some specifications call for fully spliced joints in compression as well as tension members and place no reliance upon abutting joints.

A common mistake in designing this detail is made by making the web-splice-plate and pin-plate in one piece, or making the cover-plate do as splice-plate also, or, again, if top of chord is latticed, to make the long tie-plate over pin act as splice-plate too. In the first case web-splice and pin-plate must be left off when facing the end of chord, then sent back to the riveters for riveting on of these plates and again returned to the machine-shop for boring pin-holes; in the second or third case, the whole cover-plate or long tie-plate must be left off when facing the end of chord. That these proceedings are not very economical can readily be seen.

That rivet-spacing at ends of chord sections should be closer than in the centre is understood, say four times the diameter of a rivet for a length of two diameters of member, but that they should also be closely spaced at pins, where strains are transmitted, is not always remembered. This is especially the case in deck bridges, with floor beams, but not so often forgotten as in through bridges.

As regards size of tie-plates and lattice, opinions seem to be rather divided. Most specifications call for a width of tie-plates at ends of compression members equal to one and one-half, two or two and one-half times the width of the member, but what this width is, is rather indefinite. It is also doubtful whether compression member means the whole top chord or each panel piece of chord. As good a rule as any for size of tie-plates is, probably, the following: Make tie-plates at extreme ends of compression members as nearly square as possible, and at intermediate points about half that length, the exact length being determined to suit rivet spacing, etc.

The size of lattice, as well as angle of latticing, suffers still more from diversity of opinion. Very elaborate formulas, from which to determine the size of lattice, are sometimes given. Sometimes rules are given, which, at first glance, are simple enough, but when applied to each individual case by actual figures become great consumers of time. Most generally, tables are given, which give the sizes of lattice for different channel sections, but almost every engineer has a different opinion of what is really necessary for each case. The following table will give a pretty fair average for sizes of lattice, which should make an angle of about 60°, but never less than 45°, with the axis of member. When depth of built or rolled channel section is:

6 inches or under lattice should be $1\frac{3}{4}$ inches × $\frac{1}{4}$ inch.

6 to 8	inch	lattice	should be	$1\frac{3}{4}$	inches	× $\frac{5}{16}$	inch.
8 to 10	"	"	"	2	"	× $\frac{5}{16}$	"
10 to 12	"	"	"	$2\frac{1}{4}$	"	× $\frac{5}{16}$	"
12 to 14	"	"	"	$2\frac{1}{2}$	"	× $\frac{3}{8}$	"
14 to 16	"	"	"	$2\frac{1}{2}$	"	× $\frac{7}{16}$	"
16 to 18	"	"	"	$2\frac{3}{4}$	"	× $\frac{3}{8}$	"
18 to 20	"	"	"	3	"	× $\frac{3}{8}$	"
20 to 22	"	"	"	3	"	× $\frac{7}{16}$	"
22 to 24	"	"	"	$3\frac{1}{2}$	"	× $\frac{7}{16}$	"
24 to 27	"	"	"	4	"	× $\frac{7}{16}$	"
27 to 30	"	"	"	4	"	× $\frac{1}{2}$	"

INTERMEDIATE POSTS.

The designing of ends of intermediate posts, of sufficient strength to transmit the strain on the post, is one of the most difficult problems the detail engineer has to solve, because the size and packing of everything else in the truss has already been determined upon before the width of posts is considered. The great variety of sections used for these posts makes this problem still more difficult. If posts are made of four angles latticed into an I-shape, parallel to chord, then width is small enough for all practical purposes; if made of four angles made into an I-shape, at right angle to chord, or of built channel section, with web at right angle to chord, the width of post must be taken into consideration when designing the rest of truss member, as not

much variation in width of post is possible; if made of channel section, with flanges turned in or out, and with webs at right angle to chord, or of four Z-bars, with their webs at right angle to chord, then width of post is absolutely determined and the other members in truss must be made to suit; if made of channel section, with flanges turned out and web parallel to chord, or of four Z-bars, with their webs parallel to chord, then it becomes necessary to cut flanges on post to get it into chord and give the post its required width. Usually, the flanges must be cut away altogether, and, sometimes, the web has to go also, and nothing is left to do but to transmit all the strain by means of the pin-plates. Of course, when this latter is done, the stiffness of unsupported flat bars in compression must be duly considered. When flanges are cut away the cut must be finished on a 45° angle, beginning with a gentle curve, or the post is very liable to split up at this point. The pin-plates must be long enough to pass the edge of the tie-plate by at least 3 inches, and preferably more, depending upon how much the flange has been cut away.

When floor beams are riveted to a channel post, the channels should be connected by means of a diaphragm, sufficiently strong to carry over half the floor-beam reaction into the outer channel, or, in other words, make both sides of posts act in unison, tie-plates and lattice not being able to perform this duty. Of course, this lattice work is not necessary opposite the diaphragm.

The above remarks relative to tie-plates and lattice on chord are equally applicable to same on post.

The omission of diaphragm, weak ends, and narrow posts have been and are still points open to criticism in existing bridges.

Suspenders.

End suspenders in through bridges should be made stiff members, designed and constructed as struts as well as suspenders. When made of eye-bars, which are the most advantageous for packing on hip pin, they should be latticed; when made of angles or channels, they should also be firmly latticed together and have pin ends detailed for tension, making sure to have suffi-

cient material across and behind pins to break suspender in the body.

As it very often, on account of extremely close quarters on the hip pin, becomes necessary to stop the channel section below top chord, and rivet pin-plates on inside of web, it will be found expedient to use a half eye-bar for pin-plate.

Insufficient material behind pin in pin-plate is a discrepancy which is sometimes found in past detailing of end suspenders.

Stiff Lower Chord.

Frequently specifications require the two end panels of lower chord to be made stiff members, which is either done by latticing the eye-bars or by building up the member of plate and angles or channels. A rather difficult task is so to pack lower chord and arrange shoe, that the latticed eyebars become parallel. If a satisfactory mechanical, as well as economical connection of floor-beam or strut and lateral can be made at intersection of suspender and lower chord, without having a pin at that point, it is preferable to make eye-bars in one piece over the two end panels. This is, however, a decidedly difficult problem to solve, and it is doubtful if it has yet been satisfactorily detailed.

End-Shoe, Expansion-Rollers and Bed-Plate.

Two of the most noticeable discrepancies in past detailing of end-shoes is the omission of the pin connection and making the height of shoe in pin-connected shoes too great for the length of its base. The omission of pin-connection prevents the shoe from adjusting itself to an even bearing on the masonry and produces bending strains in truss-members, when the truss deflects under load. Of course the pin-connection should be so constructed that end-post and shoe can move freely through a small angle; if post-bearing is wholly or in part directly over shoe-bearing, then an open joint must be made to permit of this movement. As at the hip-joint both shoe and post, or at least post, should have jaw- or check-plates to guard against side displacement.

If shoe is too high for its length the shoe will have a tendency to overturn instead of rolling, when span expands and contracts.

Sometimes shoes are built, in which webs neither bear on sole-plate, nor have sufficient rivets to transmit the reaction to the connection angles, and, as a result, the rivets give away until bearing relieves the strain on them.

As regards rollers, the old practice of using loose cast-iron rollers in a cast-iron box is a most reprehensible one, as the box is very soon filled up with dirt and as some of the rollers have little or no space between them, the span will be compelled to slide instead of roll. Good practice of to-day demands that the rollers should be made into a nest, with guide-bars holding them in a fixed relative position, and stay-rods, keeping the guide-bars a fixed distance apart. These stay-rods are often made of angle iron, so set and planed that they also do service as dust-angles; the guide-bars together with half **T**-irons, riveted to shoe and masonry-plate and fitted in between shoulders on rollers and guide-bars, form the dust protection on the sides. Instead of this latter construction an angle is often in small spans riveted to the masonry-plate outside of guide-bars for dust protection. The half **T**-iron construction, referred to above, is a much used and very satisfactory detail for holding the roller nest in its true position laterally. For short spans it is sufficient to plane the sole- and masonry-plates down one-eighth of an inch to receive the rollers, in addition to the angle on masonry-plate, to keep the roller nest in position.

In the groove and tongue device, so much used to hold the roller-nest in true lateral position, particular care should be taken that the depth of tongue is less than depth of groove, as otherwise the bearing will be concentrated on the tongue and groove with the probability of breaking the rollers.

The maximum load per lineal inch of rollers, allowed by different specifications, is somewhat variable and very small, but according to recent experiments and tests it may be raised considerably without danger to the rollers. But as it is best not to make base of shoe too small, $750\sqrt{d}$ for iron and $900\sqrt{d}$ for steel is about the right load per lineal inch of rollers.

When, on account of small permissible loading on masonry, it becomes necessary to distribute the end-reaction over a larger area than the shoe itself will cover, a cellular masonry-plate must be

used, which may be made either of cast-iron or built up of rolled iron; the webs in either case should run at right angles to webs in shoe and, if masonry-plate is made in two or more stories, webs should always cross each other in the different stories.

Floor-Beams.

Whenever possible, floor-beams should be rigidly attached to posts or their extensions, strength of connection being made from 25 to 50 per cent. in excess of that due to load. Their connection is either made by making the floor-beam web part of post-web, or by angles connecting floor-beam web to inside post-web; which is connected to outside web by means of a diaphragm. The former mode of connecting floor-beam to post, which can only be used when post has *one* web and then at right angle to chord, is without doubt the best detail used for this purpose, as rivets in joint are in double shear, but it is very troublesome connection in the erection, especially if post-web is not made a trifle thicker than floor-beam web.

When floor-beams are riveted to sides of posts, or stringers to floor-beams by means of end-angles, it is good practice to have rivets well crowded toward bottom of girders, to avoid pulling on their heads, when girders deflect. When stringers rest on top of floor-beams their webs should have stiffener angles, directly under stringers, for transmission into web of the residue of stringer-end reaction, that cannot be transmitted by flange angles directly.

When floor-beams rest on top chord they should have end stiffeners sufficiently connected to web, to transfer end-reaction to top-cord. They should also be side-braced against overturning.

To avoid bending on post, from floor-beams being riveted to them, floor-beams are sometimes suspended from pins, but it is certainly better practice to rivet them to post and provide sufficient section to withstand this bending. However, if for other reasons suspended beams are used, a single plate or eyebar-hanger, connected to web of beam in same manner as in post connection, should be used.

Faulty detailing of floor-beam connections, especially in using the loop-hanger construction, has in all probability caused more

bridge failures than any other detail in truss. A construction, very much used in past practice, is two rods at each end of beam, bent around pin, and straddling beams, extending through flange-angles or a plate under flanges. In either case, floor-beams are supported on nuts with or without check-nuts, but without end-stiffeners on floor-beams and relying altogether upon the stiffness of root in flange-angles. This is, beyond question, a seriously weak construction and should be prohibited in all railroad bridges and highway bridges with long panels.

A faulty detail, that has been common and still does often occur, is the insufficiency of rivets in end-stiffeners for transmission of end-reaction from web of plate girders to their support, as in stringer resting on floor-beam, floor-beam resting on top chord, girders in elevated structures, or viaducts, resting on girders or posts and girders on masonry.

As webs of girders are generally made one-quarter inch to one-half inch shallower than out to out of angles, they cannot transmit the end-reaction by direct bearing, and as flange-angles are not strong enough to take the bending, which would result if the reaction was transferred through flange rivets, end-stiffeners must have sufficient section and rivets, connecting same to web, to carry the end-reaction to the support. If end-reaction is great, it is better to have two sets of end-stiffeners than to put rivets too close in one pair.

Another faulty construction met with in floor-beams, especially shallow beams, is insufficiency of number of rivets between points of support and application of load. This, however, can not always be laid to the detailer, as it is often impossible to get in the required amount of rivets, and can only be remedied by designing a thicker web, or flange-angles with longer legs.

Insufficiency in number of rivets in flanges of all kinds of girders is another very common mistake in past detail work.

Stringers.

Stringers, when resting an top of floor-beams, should be spliced over beams, have stiffeners over beams of sufficient strength to transmit stringer end-reaction, and be braced sideways to beams.

When riveted to web of beams, strength of connection should be 25 to 50 per cent. in excess of that due to load. A shelf, or bracket, on floor-beam should be provided as a valuable assistant in erection. If top flange of stringer is narrow, it must be braced laterally against transverse crippling.

Formerly, length of stringers riveted between floor-beams was made one-sixteenth inch shorter than their geometrical length, to facilitate erection, but under full load, tension would then come on the rivet-heads, to avoid which, their length is nowadays made to the chord length under full load. This will, of course, cause trouble in erection, particularly in long spans, but may to some extent be remedied by so constructing the span that the trusses can be swung off the false work before putting in the stringers. To overcome this trouble altogether, each panel of stringers may be treated as an independent plate girder span, only resting upon well stiffened brackets on floor-beams, serving as piers for said spans. When so treated, stringers should be well braced laterally.

End-stringers are usually attached independently to masonry, with only a simple end-strut connecting them to end-shoe or end-post. Of course, if it is necessary to have lateral bracing for stringers, an end-frame must be provided for end-stringers. Instead of the end-strut and end-frame, a light end floor-beam is used with very satisfactory result.

Laterals and Sway-Bracing.

The design, general arrangement and detailing of top and bottom laterals and sway-bracing, as well as their connection, to truss, is a part of bridge construction on which the engineer can exercise all the ingenuity he is capable of, as the number of possible solutions, more or less satisfactory, seems to be unlimited.

As regards top laterals, with their struts, in through bridges, the best construction is, in all probability, to make the strut of same depth as chord and attach same rigidly to top and bottom flanges of chord and connect laterals to top flange, in short spans, and to both top and bottom flange in long spans, using double laterals of course; taking care to always get double shear on

lateral pin by using two plates and plain loop; or single plate and forked loop or clevis. Knee braces, rigidly connecting struts to posts, should be used, and, when depth of truss permits, full sway-bracing, instead of knee braces, should be used. To make knee braces, or sway-bracing, thoroughly effective, posts should be packed tight in chord. This is very often neglected. Top laterals and sway rods are often connected directly to pins by means of wing plates, but this should be avoided, unless the struts also are connected directly to pins by means of **U**-nuts. This wing plate connection should never be used in Sub-Pratt trusses, as sub-pins in top chord, generally, are too small for such use, and necessitate the use of very thick wing plates.

Another top lateral connection, which may be used in small spans, is to connect strut to truss-pin by means of a **U**-nut, which, in turn, is connected to strut by a smaller pin, this pin taking lateral rods also.

Portal bracing in through spans should never, except in very short spans, be connected to web of end post. Ordinarily, it consists of a latticed strut, with knee brackets fastened to upper flange, as near to the end top laterals as possible, the strain of which it is to transfer to end post. If depth of truss permits, one upper and one lower strut, connected by rods, should be used, or in long spans, with bracing under heavy strains; these struts should be box-shaped, of same depth as post, and connected to both top and bottom flange with double rods, one set in each plane. Sometimes, in very long spans, it becomes necessary to make two panels in portal bracing.

A very common mistake, in detailing portal bracing, is made in connecting same so far below pin that, a considerable bending strain on upper end of post is the result. Another faulty detail, very often met with in long spans, is the neglect to provide extra section in post to take care of the portal strain after it has entered the post. The bending that this strain subjects the post to, and which is greatest at the lower portal strut, requires a reinforcement of posts from pin to pin, and not merely from lower pin to lower portal strut, as is sometimes seen.

Details of top lateral bracing, in deck bridges, with ties rest-

ing directly on top chord, should be made similarly to those for top laterals in through bridges, except being calculated for the heavier strains.

Details of top laterals, in deck bridges with floor-beams resting on top chord, should also be made similarly to those for top laterals in through bridges, except being calculated for the heavier strains, and that floor-beams take the place of struts.

Laterals between inclined end-posts, in deck bridges, should be detailed similarly to portal bracing, with two struts and rods in through bridges; the struts may, however, be connected to pins with **U**-nuts and rods with wing plates on pins behind **U**-nuts.

Laterals, or perhaps, more properly, sway-bracing between vertical end-posts in deck bridges, are best detailed with **U**-nut connected struts, and wing-plates on both upper and lower pins, if ties rest on chord; but only on lower pin, and with bent plate under floor-beam on top, when floor-beams rest on top chord.

Lower lateral bracing in through bridges should be so designed and detailed, that the bending on floor-beams and posts is reduced to a minimum. Thus their connections should be so arranged that the strains in laterals go directly to the centre of truss-pins, both in vertical and horizontal planes, and the flange of floor-beam be on line with centre-line of pin, preferably the lower flange which, of course, calls for floor-beams riveted to posts. Doubtless the "Thatcher" floor-beam comes nearest to fulfilling the above requirements, as on it the flange is on line with pin and bent to clear bar-heads, having a shoulder bracket, riveted on at point of bend, against which the pin abuts and laterals pull, by means of a wing-plate on pin. Another good way to solve this problem is to extend post and floor-beam to a point sufficiently below pin, to clear bar-heads and connect them with a stiff horizontal plate, to which the laterals are also connected. In very short spans where strains in laterals are small, it is sufficient to connect laterals to flange of floor-beam as near to post as possible, and, if floor-beam is suspended, connect its top to post by an angle or bent plate. In very long spans requiring large sections in laterals, and having only single system of rods below or above chord, the bending on post should be taken up by rods connecting

a point up in post to the adjacent truss-pins. It is, however, better to divide the section on two systems of rods, one above and one below chord, connecting both to a U-plate on centre of pin, and which is attached by both wings to floor-beam flange, this latter being bifurcated.

Lower lateral bracing in deck bridges is best detailed by connecting struts to pins by means of U-plates and rods with wing-plates, also on pins, behind U-nuts. Rods may also be connected to small pins which, in turn, connect struts to U-nuts.

Sway rods in deck bridges are best connected to the extended tie-plates of top and bottom struts. Another connection somewhat inferior, which frequently is used, is by wing-plates to chord-pins behind strut U-nut connection or by bent plate to cover-plate of top-chord, when floor-beams serve as top-struts.

Sway-rods at intermediate posts, as well as at end-posts, are sometimes connected directly to post by running them through and checking them against the web, but this is liable to be somewhat troublesome in erection.

Laterals and sway-bracing are sometimes made stiff and non-adjustable, but this makes considerable trouble in erection, especially in top-laterals and sway-bracing.

Faults, more or less serious, in detailing lateral and sway-bracing connections, especially in laterals for loaded chord, may be discovered on nearly all bridges and are all directly traceable to the well-nigh practical impossibility of so constructing the details that the strains in all the members composing the wind-strut will follow its geometrical centre-lines in one plane. It is curious to note how some detailing engineers are trying to accomplish this. They seem to think that if only centre-line of diagonal goes through intersection of strut and chord, it does not matter if the strain has to travel in a roundabout way through the detail to get to this intersection.

In addition to the above faults we often in past practice find details of insufficient strength to develop the full strength of lateral; especially is this the case in scantiness of bearing-surface and shearing area.

Discussion.

Mr. Roberts: It is one of the most valuable papers we have ever had read before our Society. I believe it will become standard in the matter of details.

Mr. Wilkins: I think the discussion of this paper had better be deferred until the next meeting. After it is in print the members will have more of a chance to read it and look up points to discuss. It is pretty hard to keep all these points in your mind now.

Mr. Becker: The elaboration of the details of bridge structure has developed into a minute specialty which is generally taken care of by the young men that are now spending their days at the drawing boards. Old fellows like myself are seldom called upon to do anything of that sort. It is just about as much as we can do to look after the principal engineering features of a railroad in a general way. When we come to a river we make up our minds that there is a bridge necessary, and when we think there is a bridge needed we arrive at some guess as to the capacity of the water-way, and then we will take into consideration the questions of foundations and other circumstances which will lead us to determine the number and length of spans.

Then we also have some crude notions as to what the bridge ought to carry. From all these detached data we make some sketch or diagram and send it out to the bridge companies, of which there are quite a number in this country now. We let them bid upon a strain sheet that gives them a skeleton outline, sizes of the panels, and the required dimensions of the members to resist the strains that are liable to come upon them. From the responses that we receive to our circulars we make up our mind as to who shall get the contract. It depends a little upon the dollars and cents.

We generally have it understood that when we give the contract out it is upon the condition that the details are to be made satisfactory. As to whether they are satisfactory or not, we have no trouble finding some young man, having some experience in that line of business, who sits down and finds out whether the details have been made satisfactory. We may find that

some of them are not and we generally arrange to give the work to the party who has given us the best detail, the general outlines being mostly prescribed by ourselves.

I am really not fit to tell much about this subject. I would like to see the paper in print and read it over carefully. I think that perhaps there are some points in it where our experience about the fitness of some things and the unfitness of others will enable me to talk more intelligently. When the paper is in print I shall be glad to read it over and have something to say at the next meeting.

I would like to ask Mr. Swensson one question with reference to an occurrence that happened to one of our bridges about a year ago. The bottom chord was pinned together with a steel pin, I think five inches in diameter, reduced at the ends to a diameter of about three inches, with a screw-thread cut on for the purpose of receiving the pilot-nut. Upon this reduced diameter on which the screw-thread was cut there was a so-called **U**-plate attached on the inside of the chord, which again held the lateral strut. Before the bridge was up a week, and before it had been properly adjusted, the reduced end of that steel pin broke bodily off. I never could understand quite fully what could have induced that break.

Mr. Swensson: What kind of steel was it?

Mr. Becker: Bessemer steel, filling the specifications. It had been inspected by our own inspector as to quality. Now what could have induced the occurrence? It might have led to serious trouble, but it did not in this case, because it happened too soon.

Mr. Swensson: I do not think that has anything to do with detailing. It might have been due to a flaw in the pin before it was turned, or caused at the time the steel was made at the steel works, and had not been noticed. Being made of Bessemer steel it might be due to some of the faults of said steel which we know it is liable to have.

Mr. Roberts: Did the fracture indicate a flaw?

Mr. Becker: The fracture was a very clean break and right at the reduction from the large to the small diameter. My idea, and the only explanation that I could give, was, that when the

pilot-nut was put on some violence was used in driving the pin, starting the fracture. There might have been some slant blow given, but I was told that the pin was driven from the other end.

Mr. Swensson: How many years ago was it?

Mr. Becker: Two years ago.

Mr. Swensson: Was it high steel, 70,000 to 75,000 steel?

Mr. Becker: I cannot give the details now. I can say in general terms only, that it was the quality of steel prescribed in our specifications for pins.

Mr. Lewis: I believe in machine design, at least, that those square shoulders, that is where a shaft say is shouldered down, they are rather careful not to work it out to a square angle, that is, a reduction to a square angle with a reduced end, leaving a fillet there. It may be that this break was, in a manner, induced by turning down squarely to a sharp corner.

Mr. Becker: It was cut down to a sharp corner.

Mr. Roberts: I am reminded by that break of a mysterious break that Mr. Metcalfe told us about one time, where a steel shaft, after being turned nicely, had a tool dragged over it, which made a fine hair crack around the shaft. The shaft broke along that line. Now there may have been something like that occurred in the turning at that point. There may have been an initial score, or it may not have been properly annealed, or something of that sort.

Mr. Hutchinson: I think that in this case there was more than a simple initial scoring, but there was probably a score there which would facilitate the breaking. It would start the crack.

Mr. Brashear: Captain Hunt was telling me of a very curious case that came under his observation week before last that might have some bearing on this. They were making some pulls of a piece of Bessemer steel, I think two or three inches in diameter, and if I remember aright it broke at a very small pull. When they came to trace it they found that the man who prepared the test-piece, in order to get a proper hold, had made a very small centre-punch mark, not more than the size of the head of a pin. There seemed to be a shock across the entire piece of steel. They could hardly believe that was the cause, and so they

made a second punch mark and pulled the steel, and the same occurred. It seemed as if a shock had been transmitted across the bar: They put it in the microscope, and they could see the strains running across that bar, and this from that centre-punch mark. I have had very curious instances of that kind occur in my rolling mill life, but never ran across anything so curious as that.

MR. ROBERTS: You say the lines were indicated by the microscope?

MR. BRASHEAR: The lines were indicated over the whole diameter. They radiated from this centre-punch mark.

MR. SCAIFE: I noticed a case not long ago, which may bear somewhat on this point. We had some $1\frac{1}{2}$-inch steel bolts, to be used for bridge work, and, in putting together the work, had occasion to draw up very hard on one of these bolts. The bolt was broken off at one of the threads, simply by the strain put by a couple of men on a long wrench. The fracture was perfectly clean and showed good steel. It seems to me, from this and other cases I have noticed, that steel is not a good material to use for bolts where the strain may be brought on a sharp edge or shoulder.

MR. SWENSSON: As an illustration of quality of a Bessemer steel a 6 x 6 angle, $\frac{7}{8}$-inch thick, punched with a $\frac{7}{8}$-inch hole, dropped nine to twelve inches from an elevation, broke right off. I think the trouble was that the cast-iron had not been given time to become thoroughly decarbonized in the converter. Instead of boiling it 20 or 30 minutes, they do it in 12 or 15 minutes in Bessemer steel. Inspection even the most careful cannot tell that, unless they inspect from the time the cast-iron goes in, and hardly then can inspection discover possible pipings or imbedded impurities in the cast ingots.

MR. ROBERTS: I have had wrought-iron spikes break into three pieces under one blow of a hammer. That was charcoal iron, so called?

MR. LEWIS: I should like to know the utility of the intermediate sway-bracing where the column is figured for its full length and breadth, that is not figured as bisected by the sway-bracing. Most specifications call for the sway-bracing from a

certain depth or truss, at the same time they either state clearly or expect that the column shall be figured the length. I would like to inquire what is the utility of that sway-bracing; that is, what modes or circumstances should be provided against by it.

Mr. Swensson: I do not suppose that question can be answered by me. I suppose that some of the gentlemen who write specifications will reply. It does not come within the "young man's" details. We simply put sway-bracing in because they are called for and do it the best we know how.

Mr. Becker: I should say that the sway-bracing when provided for in the specification is intended to equalize the stresses on the two opposite trusses or plate-girders, as the case might be, and compensate for the inequality of the moving load. We know that cars sometimes go over a road a little lop-sided. They carry a little more on one side than on the other, and to provide for this undue force not equally divided between the two trusses, and to prevent any undue vibrations induced by that sort of an unequal loading, the sway-bracing is put in. I do not know whether anybody knows any other reason. If so I would like to know.

Mr. Hutchinson: One thing that occurred to me when the paper was being read was in regard to the first principles of details which were not mentioned. That is their simplicity. I think that should be one of the first and governing principles. It will appear in every process. It helps in the design. Of course you will get better results in the shop, and you will be very much more likely to get your stresses where you wish to have them go.

Mr. Becker: There is one point I would like to call attention to. Of course it is not such a very difficult thing now with our knowledge that has been acquired by experience largely, and also by theoretical study, to design a new structure, in the best light of our knowledge, and make it as nearly perfect as it can be made. But we old fellows did not know so much when we started out some years ago and we put some rather unreasonable attachments on some of our bridges, and they are still there. They are sometimes a little bad, but not bad enough to throw the whole bridge into the scrap pile.

Now I think that a man reading a paper on details ought to

have gone a little further and told us a little something about remedying some of these minor defects, what methods to adopt to get over the old faults of our forefathers and still, for economical reasons, preserving the main structure, which may be in fair condition, and with a little assistance could be tinkered up and do service for a good long time to come. There are a great many such cases, and I think if some of the gentlemen would look upon that part of the subject a little and take up a discussion from that point of view we might learn something worth knowing.

I know that we are spending some money all the time to prevent things from getting worse and making them do a little longer; in other words, remedying some of those manifest clumsy mistakes that were made in the past. We generally find a way to get over it, and to make the structures last a little while longer.

I will mention, for instance, this question of floor-beam hangers on pin-yokes. We all know that is a very bad thing. Nobody disputes it and I may say that two of them are worse than one. Most of the bridges have two. On those two pins, generally on the extremities, are two pin-yokes that hold up the floor-beam which carries the entire moving load of that bridge. That floor-beam is deflected by its load in the middle. The two inner yokes will have good deal more of a deflection than the two outer ones. Just how much more I would not attempt to say. When the floor-beams are a little weak, as they probably are in old bridges, they will go down under the load. Now I do not know what else you would put in such a bridge and hold these floor-beams up. If you don't, are you going to throw the whole bridge in the scrap pile?

Mr. Swensson: The "young man" who nowadays designs on bridge details has enough to do to construct new ones, to understand and live up to all the different specifications that come in his hands, and when a repair job comes in I can tell you we love it. I have dreamed of that old Monongahela bridge over there more than once. The repairs on that bridge have worried us considerably, and I think it is time they got a new one.

To remedy such things as floor-beam hangers I do not see is so very difficult. Get new floor-beams and put in plate-hangers from the middle of pin. That is the best remedy I see. You have

one hanger, a plate-hanger. That is not so hard to put it in. "Study up and find out how best to repair old structures in existence." I do not think the "young man" is familiar enough with old structures. In the second place they have not time or patience. They would rather build new and try to do it better.

MR. JOHNSON: Mr. Swensson refers to the substitution of plate-hangers. If he will stop and consider, that means taking the bridge all apart and putting it together again, because they will go into the middle of the bridge.

MR. BECKER: That would be the last thing to think of, putting in the plate-hanger in the middle of the pin. The pin is probably a little light, and when you have the shearing reduced to a minimum by bringing the two hangers close to the post footings, taking them away and substituting a single plate-hanger in the middle, you naturally increase the bending moment very largely. You will have to drive your pin out and get your new one in, and carry your bridge with false work until it is all done. Rather than go to all that trouble I would build a new bridge. In one case we have used a little equalizer plate, slightly rounded, holding it by these two straps. We rest our floor-beam on the point midway between the two hangers. That is better than building a new bridge. It cost us about $100, and a new bridge would have cost $8000.

MR. SWENSSON: That is just the point; the pin is probably a little light, and so is most everything else in an old bridge. The moral is, therefore: Build a new bridge, and do not tinker with the old.

MR. ROBERTS: The point of value in Mr. Swensson's paper is where he draws attention to the transfer from one member to another. That takes into account the different kinds of strains that may come in those details. In that regard I think his information very valuable for future bridge builders.

MR. SCAIFE: I should like to ask if anything has ever been done by any railroad or bridge engineer to determine from actual experiment the strains which occur in any of their bridges. A number of years ago, in France, I heard a machine described, which was used there somewhat, and which, in some form or other, it seems to me, could be used to advantage in this country

to determine how far the the strain sheets sent out represent what actually occurs in practice. Occasionally we have a bridge break down, lives are lost, a great deal of property destroyed, and many people suffer, except the "young man." It may be that there are certain assumptions made in these calculations which are not always verified by practice. The principle of this machine was as follows: Suppose you have a member of a bridge in which it is desired to find the strains that occur. Two small holes or attachments are made. To these points are attached the movable points or fulcrums of a little machine, the whole object of which is to represent by the movable arm a magnified image of the movements of this member. Such an instrument could be very easily attached either to the top or bottom chords or cross members, and I think might help to some interesting results.

Mr. Becker: The only thing I know of was the attempt of a learned professor in a technical school, who calculated that if a fiddle-string sustaining a certain amount of tension would give so many vibrations per second, and would produce low G or high F, as the case might be, that the members of a bridge might be tuned up the same way; that if loaded to a certain strain they would sing one song, and if they were not properly loaded they would sing another. So that he might go on a bridge and play some tune like Yankee Doodle, and if there were no false notes the structure would be all right.

Mr. Brashear: I might mention that telescope makers are called upon to help find these strains occasionally. We received an order not long since from an Eastern college for some glass rollers, which they proposed to use in studying the strain of a bridge. They were going to get the results by the study of the polarization caused in the glass by the pressure on it. I have never heard any results from it, but we were very careful in making the glass. We know what the effect of pressure is on glass.

We determine the rotation of our emery-wheels by the song they sing.

Society adjourned.

R. N. Clark,
Secretary pro tem.

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Dec. 16, '90.	Abbott, W. S.,	48 Fifth Av., Pittsburg, Pa.
May 21, '80.	Aiken, Henry,	508 Lewis Building, Pittsburg, Pa.
Mar. 20, '88.	Aikman, Edw. G.,	115 Broadway (Room 95), New York.
Oct. 20, '85.	Albree, C. B.,	18 Market St., Allegheny, Pa.
Apr. 20, '80.	Amsler, Chas., M.E.,	Bissel Block, Pittsburg, Pa.
Dec. 16, '84.	Anderson, J. W.,	45 Fremont St., Allegheny, Pa.
Jan. 6, '80.	Armstrong, H. W.,	Metcalf, Paul & Co., Pittsburg, Pa
Jan. 18, '87.	Arms, W. F., M.E.,	R. & P. C. & I. Co., Punxsutawney, Pa.
Nov. 20, '88.	Arras, John W.,	P. O. Box 485, Pittsburg, Pa.
Apr. 15, '60.	Ashworth, Daniel,	Shannon Building, 108 4th Ave., Pittsburg, Pa.
Apr. 21, '91.	Atwood, S. A.,	Beaver Falls, Pa.
Feb. 21, '82.	Aull, W. F., C.E.,	Manager Denny Estate, Box 91, Pittsburg, Pa.
Jan. 6, '80.	Awl, John L.,	Mgr. Monong. Incline Plane, Pittsburg, Pa.
Sept. 20, '87.	Bailey, Chas.,	Reliance Steel Casting Co., 36th St. and A. V. R. R., Pittsburg, Pa.
Sept. 16, '84.	Bailey, Jas. M.,	Mfr. Sligo Iron Works, Pittsburg, Pa.
May 18, '84.	Bakewell, Thos. W.,	Bakewell Building, Pittsburg, Pa.

Date of Membership.		
June 19, '88.	Bakewell, Wm.,	110 Diamond St., Pittsburg, Pa.
Apr. 17, '88.	Barbour, Geo. H.,	Barbour, Gilfillan & Taylor, Chicago, Ill.
May 19, '85.	Barnes, Phineas,	Jones & Laughlins, Ltd., Pittsburg, Pa.
May 20, '90.	Barret, J. H.,	134 Jackson St., Allegheny, Pa.
Nov. 21, '82.	Bates, Onward,	Rand & McNally Bldg., Chicago, Ill.
Jan. 6, '80.	Becker, Max J.,	C. Eng., P., C. & St. L. Ry., Pittsburg, Pa.
Jan. 20, '85.	Beckfield, Chas.,	804 Duquesne Way, Pittsburg, Pa.
Nov. 19, '89.	Bell, W. G.,	P. O. Box 976, Pittsburg, Pa.
Dec. 18, '83.	Benney, Jas.,	Emsworth, Pa.
Jan. 6, '80.	Bigelow, E. M.,	Chf. of Dept. of Public Wks., Pittsburg, Pa.
Feb. 19, '89.	Billen, C. E.,	Supt. Bridge & Const. Dept. Penna. Steel Co., Steelton, Pa.
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Sept. 18, '83.	Blank, Hugo,	Chemist, 77 4th Ave., Pittsburg, Pa.
Jan. 11, '89.	Blaxter, G. H.,	Allegheny Co. Light Co., Pittsburg, Pa.
Mar. 18, '84.	Bole, W. A.,	Supt. West'ghouse Mach. Co. 25th and Liberty Sts., Pittsburg, Pa.
Jan. 6, '80.	Borntraeger, H. W.,	Carnegie Phipps Co., Pittsburg, Pa.
Apr. 19, '81.	Boyd, Henry A.,	National Tube Works, McKeesport, Pa.
Mar. 18, '84.	Brashear, John A.,	Optician, Observatory Ave., Allegheny, Pa.

Date of Membership.		
Feb. 17, '91.	Branne, J.,	Keystone Bridge Co., Pittsburg, Pa.
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Jan. 6, '80.	Brendlinger, P. F.,	79 Warburton Ave., Yonkers, N. Y.
Jan. 19, '86.	Brockett, Alonzo H.,	Mellor & Hoene, Fifth Ave., Pittsburg, Pa.
Jan. 6, '80.	Browne, Geo. H.,	Supt. Water Works, Pittsburg, Pa.
Jan. 6, '80.	Brown, W. R.,	City Engineer's Office, Pittsburg, Pa.
Apr. 18, '82.	Brunot, H. J.,	Greensburg, Pa.
Jan. 18, '87.	Buente, C. F.,	Stone Contractor, Duquesne Way & 10th St., Pittsburg, Pa.
Jan. 6, '80.	Bullock, W. S.,	Taylor & Bullock, Pittsburg, Pa.
Sept. 21, '80.	Burgher, Rutherford,	Treasurer Kidd Steel Wire Co., Ltd., Harmarville, Pa.
Jan. 19, '86.	Cadman, A. W.,	Brass Manufacturer, Pittsburg, Pa.
Dec. 20, '87.	Campbell, Hugh C.,	187 Sandusky St., Allegheny, Pa.
May 23, '82.	Camp, Jas. M.,	Duquesne, Pa.
Feb. 20, '83.	Carhart, Danl.,	Prof. Math. and Eng., Western University, Allegheny, Pa.
May 19, '85.	Carlin, Thos. H.,	Machinist, 186 Lacock St., Allegheny, Pa.
Nov. 18, '84.	Carlin, David,	Mgr. W. G. Price & Co. Iron and Lead Works, 5th Ave. and Price St., Pittsburg, Pa.
Dec. 16, '90.	Carnahan, R. B.,	Care W. D. Wood, McKeesport, Pa.

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Apr. 20, '80.	Carnegie, Andrew,	Steel, 55 Broadway, New York.
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Sept. 18, '83.	Chambers, J. S., Jr.,	C. E., 19 Church Ave., Allegheny, Pa.
Feb. 17, '80.	Chess, H. B.,	Chess, Cook & Co., Nails and Tacks, Pittsburg, Pa.
Nov. 21, '82.	Clapp, Geo. H.,	Chemist, 95 and 97 Fifth Ave., Pittsburg, Pa.
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Jan. 18, '88.	Clark, R. N.,	Pgh. Rustless Iron Co., 32d and Smallman Streets, Pittsburg, Pa.
Sept. 15, '91.	Clugston, W. A.,	531 Wood St., Pittsburg, Pa.
Oct. 16, '83.	Coffin, Wm. C., Jr.,	Draughtsman, 66 Western Ave., Allegheny, Pa.
Apr. 19, '87.	Colby, J. A.,	Girard Building, Philadelphia, Pa.
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May 19, '91.	Connelly, C. B.,	Western University, Allegheny, Pa.
Feb. 22, '81.	Cooper, Chas. H.,	Bakewell Building, Pittsburg, Pa.
Dec. 20, '81.	Cooper, John W.,	Draughtsman, Pitts. Locomotive Works, Allegheny, Pa.
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Date of Membership.		
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Jan. 6, '80.	Edeburn, W. A.,	Eng. and Surveyor, Bakewell Building, Pittsburg, Pa.
Mar. 18, '91.	Edwards, J. P.,	Uniontown, Pa.
Jan. 6, '80.	Ehlers, Chas.,	City Eng., No. 8 City Hall, Allegheny, Pa.
Jan. 19, '92.	Emmons, C. DeMoss,	Dithridge and Forbes Sts., Pittsburg, Pa.
Feb. 27, '88.	Engle, Geo. W.,	Eng. Gen. Office. Penna. Co., Pittsburg, Pa.
Sept. 19, '82.	Engstrom, F.,	Engineer, Penna. Co., Pittsburg, Pa.
Feb. 4, '88.	Estrada, E. D.,	Lewis Block, Pittsburg, Pa.
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Jan. 18, '87.	Follansbee, Gilbert,	Supt. Chamber of Commerce, Pittsburg, Pa.
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Apr. 21, '91.	Forter, S.,	Lewis Block, Room 702, Pittsburg, Pa.
Feb. 21, '82.	Frank, Isaac W.,	Founder, Lewis Foundry Co. Pittsburg, Pa.
Jan. 6, '80.	Frost, A. E.,	Prof. of Physics, W. U., Perryville Ave., Allegheny, Pa.
Apr. 17, '88.	Fulton, Louis B.,	Chancery Lane, Pittsburg, Pa.
Apr. 15, '90.	Giles, W. A.,	Schmidt Bldg., Pittsburg, Pa.
Oct. 16, '83.	Glafey, Frederick,	Keystone Bridge Works, Pittsburg, Pa.
Feb. 17, '80.	Goodyear, S. W.,	Waterbury, Conn.
Jan. 6, '80.	Gottleib, A.,	Room 75, Major's Block, Chicago, Ill.
June 16, '85.	Grant, Horace E.,	119 First Ave., Pittsburg, Pa.
Apr. 21, '85.	Griffen, A. L.,	Keystone Bridge Co., Pittsburg, Pa.
Jan. 19, '92.	Griffen, Francis A.,	319 S. Highland Ave., Pittsburg, Pa.
Sept. 19, '82.	Gwinner, Fred., Jr.,	Contractor, Allegheny, Pa.
Mar. 20, '83.	Hackett, Geo. W.,	Cement, Lime and Terra Cotta, 1009 Library St., Pittsburg, Pa.
Dec. 16, '90.	Hall, Chas. M.,	95 Fifth Ave., Pittsburg, Pa.
Feb. 17, '91.	Hallgren, Emil,	419 Bissel Block, Pittsburg, Pa.
May 17, '80.	Hammer, Hakon,	4605 Fifth Ave., Pittsburg, Pa.

Date of Membership.		
Oct. 15, '89.	Handy, J. O.,	95 Fifth Ave., Pittsburg, Pa.
Feb. 17, '91.	Hardie, J. B.,	Keystone Bridge Co., Pittsburg, Pa.
Jan. 6, '80.	Harlow, Jas. H.,	Hydraulic Engineer, 108 4th Ave., Pittsburg, Pa.
Apr. 19, '81.	Harlow, Geo. R.,	Hydraulic Engineer, 108 4th Ave., Pittsburg, Pa.
Nov. 25, '91.	Hartrick, R. S. D.,	134 Water St., Pittsburg, Pa.
Jan. 6, '80.	Hemphill, Jas.,	Machinist, Mackintosh, Hemphill & Co., Pittsburg, Pa.
Nov. 14, '85.	Heron, Fred.,	Supt. Phœnix Iron Works, Phœnixville, Pa.
Jan. 19, '86.	Hetzel, Jas.,	60 Fourth Ave., Pittsburg, Pa.
Apr. 19, '87.	Hibbard, H. D.,	High Bridge, N. J.
Nov. 20, '88.	Hoag, I. V., Jr.,	43 Sixth Ave., Pittsburg, Pa.
Apr. 20, '80.	Hoffstot, Frank N.,	Iron Broker, Water St., Pittsburg, Pa.
Sept. 18, '88.	Hohl, L. I.,	Ruth St., 32d Ward, Pittsburg, Pa.
Dec. 18, '88.	Holland, W. J.,	Fifth Ave., Oakland, Pittsburg, Pa.
Nov. 15, '87.	Hopke, T. M.,	Linden Steel Co., Pittsburg, Pa.
Oct. 16, '88.	Howe, H. M.,	287 Marlboro St., Boston, Mass.
cOt. 18, '81.	Hunt, A. E.,	C. & M. E., 97 Fifth Ave., Pittsburg, Pa.
Jan. 22, '89.	Hunt, H. E.,	Emerson St., E. E., Pittsburg, Pa.
Oct. 21, '90.	Hutchinson, G. H.,	Keystone Bridge Co., Pittsburg, Pa.
Oct. 18, '87.	Hyde, C.,	Room 902, Lewis Bl'k, Pittsburg, Pa.

Date of Membership.		
Mar. 18, '80.	Jarboe, W. S.,	14 Garfield Ave., Allegheny, Pa.
Dec. 18, '88.	Jenkins, J. B.,	98 Arch St., Allegheny, Pa.
Feb. 22, '81.	Jennings, B. F.,	Preble Ave, Allegheny, Pa.
Sept. 15, '91.	Jennings, W. H.,	P. & L. E. R.R., Pittsburg, Pa.
Jan. 18, '88.	Johnson, Thos. H.,	Penna. Lines, Tenth and Penn Sts., Pittsburg, Pa.
Apr. 19, '81.	Jones, B. F.,	Iron Manufacturer, Pittsburg, Pa.
Dec. 15, '91.	Jones, Jesse,	94 Buena Vista St., Allegheny, Pa.
Mar. 20, '88.	Jones, W. Larimer,	Jones & Laughlins, Ltd., Pittsburg, Pa.
Nov. 16, '80.	Kaufman, Gustave,	814 Hamilton Building, Pittsburg, Pa.
May 16, '80.	Kay, J. C.,	Machinery, Kay Bros. & Co. Water St., Pittsburg, Pa.
Feb. 17, '85.	Kay, Jas. I.,	Patent Attorney, 96 Diamond St., Pittsburg, Pa.
May 21, '89.	Keenan, J. J.,	Hollidaysburg, Blair Co., Pa.
Mar. 17, '85.	Kelly, J. A.,	28th and Smallman Sts., Pittsburg, Pa.
Jan. 16, '85.	Kelly, J. W.,	Box 196, New Brighton, Beaver Co., Pa.
Oct. 20, '91.	Kelly, M. B.,	61 Wylie Ave., Pittsburg, Pa.
Feb. 17, '91.	Kemler, W. H.,	1823 Carson St., Pittsburg, Pa.
May 18, '86.	Kennedy, Julien,	Latrobe, Pa.
Sept. 19, '82.	Kenyon, L. H.,	Pitts. Locomotive Works, Allegheny, Pa.
Mar. 19, '89.	Kerr, A. C.,	Third Ave., Pittsburg, Pa.

Date of Membership.		
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June 19, '88.	Kimball, Frank I.,	Mining Engineer, Greensburg, Pa.
Feb. 21, '82.	King, T. M.,	B. & O. R.R., Baltimore, Md.
Mar. 16, '82.	Kirk, Arthur,	Sharpsburg, Pa.
Nov. 15, '87.	Kirtland, A. P.,	Acmetonia, Pa.
Apr. 19, '87.	Klages, Geo. W.,	Machinist, Foreman, 130 Eleventh St., S. S., Pittsburg, Pa.
Apr. 19, '87.	Koch, Walter E.,	Supt. Spang's Steel Works, Sharpsburg, Pa.
Jan. 6, '80.	Laing, Geo.,	Commission Merchant, Chicago, Ill.
Nov. 20, '88.	Langley, J. W.,	136 First Ave., Pittsburg, Pa.
May 19, '85.	Lauder, Geo.,	48 Fifth Ave., Pittsburg, Pa.
June 19, '88.	Lean, D. R.,	Lean & Blair, Engineers and Contractors, Pittsburg, Pa.
Jan. 17, '88.	Leech, Louis D.,	44th St. and Centre Ave., Pittsburg, Pa.
Apr. 15, '84.	Leishman, John A. G.,	Lewis Block, Pittsburg, Pa.
May 16, '80.	Leschorn, Alex.,	M. E., Phœnix Bridge Co., Phœnixville, Pa.
Mar. 16, '80.	Lewis, J. L.,	Lewis Foundry and Machine Co., Ltd., Pittsburg, Pa.
Apr. 20, '80.	Lewis, W. J.,	Linden Steel Co., Pittsburg, Pa.
May 20, '90.	Lewis, H. J.,	Keystone Bridge Co., Pittsburg, Pa.
Feb. 21, '82.	Lindenthal, Gustave,	Engineer, Lewis Block, Pittsburg, Pa.
Oct. 16, '88.	Linkenheimer, A. E.,	141 Federal St., Allegheny.
Sept. 16, '84.	Lloyd, Henry,	Iron Mfr., Lewis Block, Pittsburg, Pa.
May 19, '81.	Lloyd, John W.,	Iron Mfr., H. Lloyd, Sons & Co., Pittsburg, Pa.

Date of Membership.		
Nov. 18, '90.	Lobingier, J. E.,	Euclid and Friendship Ave., Pittsburg, Pa.
Oct. 19, '80.	Loomis, Geo. P.,	Iron Manufacturer, Harmarville, Pa.
Sept. 16, '90.	Ludwig, Jos.,	525 State St., Schenectady, N. Y.
Jan. 6, '80.	Macbeth, Geo. A.,	Keystone Flint Glass Co., Pittsburg, Pa.
Apr. 19, '81.	Malone, M. L.,	Engineer, 320 Fifth Ave., Pittsburg, Pa.
Jan. 6, '80.	Martin, Wm.,	Resident Eng., Davis Island Dam., P. O. Box 670, Pittsburg, Pa.
Dec. 18, '83.	Mead, Edwd.,	P. O. Box 124, Louisville, Ky.
Feb. 17, '91.	Means, E. C.,	Westinghouse Electric Co., Pittsburg, Pa.
June 18, '89.	Mellor, Walter C.,	77 Fifth Ave., Pittsburg, Pa.
Sept. 16, '90.	Mercàder, Camille,	Edgar Thompson St'l Wks., Braddock, Pa.
Mar. 20, '88.	Mesta, Geo.,	Lewis Block, Room 512, Pittsburg, Pa.
Jan. 6, '80.	Metcalf, Wm.,	Crescent Steel Works, 49th and R. R. Sts., Pittsburg, Pa.
Jan. 15, '84.	Meyran, L. A.,	Canonsburg Iron and Steel Co., Germania Bank Bldg., Pittsburg, Pa.
Sept. 18, '83.	Miles, Geo. K.,	Sec. and Treas. Charlotte Fur Co., Pittsburg, Pa.
Feb. 21, '82.	Milholland, J. B.,	Engine Builder, Fifth Ave., Pittsburg, Pa.
Jan. 6, '80.	Miller, Reuben,	136 1st Ave., Pittsburg, Pa.
May 19, '85.	Miller, Wilson,	Sec. Pittsburg Loco. Works, 18 Lincoln Ave., Allegheny, Pa.

Date of Membership.		
Oct. 19, '80.	Milliken, A. C.,	Pottsville Iron and Steel Co. Pottsville, Pa.
Apr. 19, '81.	Moorhead, M. K.,	Moorhead-McClean Co., Pittsburg, Pa.
Mar. 15, '81.	Morgan, Jas.,	2204 Carson St., Pittsburg, Pa.
Apr. 15, '90.	Morgan, Wm.,	2 Sixth St., Pittsburg, Pa.
Oct. 19, '86.	Morris, G. W.,	P. O. Box 656, Pittsburg, Pa.
Jan. 21, '90.	Morris, H. Saunders,	Westinghouse Electric Co., Pittsburg, Pa.
May 15, '83.	Morse, H. C.,	Engineer, Edgemoor, Del.
Mar. 18, '90.	Mueller, Gustave,	78 Second St., Allegheny, Pa.
Apr. 15, '80.	Munro, R.,	Boiler Manufacturer, 23d and Smallman Sts., Pittsburg, Pa.
Mar. 16, '80.	McCandless, E.. V,	Merchant, Pittsburg, Pa.
Jan. 20, '91.	McClintock, H. P.,	McClintock & Irvine, S. Ave. and Snowden St., Allegheny, Pa.
May 19, '85.	McConnell, John A.,	69 Water St., Pittsburg, Pa.
Mar. 15, '81.	McCulley, R. L.,	101 Fifth Ave., Pittsburg, Pa.
Feb. 22, '81.	McCune, John D.,	98 Fourth Ave., Pittsburg, Pa.
May 21, '89.	McDonald, John,	239 Forty-fourth St., Pittsburg, Pa.
Dec. 17, '89.	McDonald, C. J.,	143 Fayette St., Allegheny, Pa.
Apr. 18, '87.	McDowell, James,	Optician, Observatory Ave., Allegheny, Pa.
Oct. 21, '90.	McFarland, N. J.,	Pittsburg, Pa.
Dec. 16, '90.	McIntyre, J. B.,	131 Urania Ave., Greensburg, Pa.
Jan. 20, '91.	McKaig, Thos. B.,	95 Fifth Ave., Pittsburg, Pa.
Sept. 21, '80.	McKinney, J. P.,	60 Sheffield St., Allegheny, Pa.
Jan. 16, '83.	McKinney, R. M.,	Elizabeth, Pa.

Date of Membership.		
Mar. 15, '81.	McLennan, Alex.,	56 Sec'nd Ave., Pittsburg, Pa.
Feb. 21, '82.	McMurtry, Geo. G.,	Pittsburg, Pa.
Feb. 17, '85.	McQuiston, Jas.,	26th and Railroad Sts., Pittsburg, Pa.
Mar. 15, '81.	McRoberts, J. H.,	400 Grant St., Pittsburg, Pa.
Jan. 6, '80.	Naegley, John,	Eng. and Architect, Room 9, Renshaw Bldg., Liberty & 9th Sts., Pittsburg, Pa.
Jan. 19, '86.	Nevins, Richard, Jr.	Seattle, Washington.
Jan. '81.	Nichols, T. B.,	223 Allegheny Ave., Allegheny, Pa.
Apr. 20, '80.	Nimick, F. B.,	Steel Mfr., Singer, Nimick & Co., Pittsburg, Pa.
Feb. 21, '82.	Noble, Patrick,	Pacific R. M. Co., 202 Market St., San Francisco, Cal.
Feb. 20, '83.	Paddock, Jos. H.,	Civil Engineer, Connellsville, Pa.
Nov. 18, '90.	Page, Benj.,	Monon. Con. R. R., 3d Ave. and Try St., Pittsburg, Pa.
May 21, '89.	Paine, G. H.,	Swissville, Pa.
Mar. 18, '84.	Painter, Park,	Iron Mfr., J. Painter & Sons, Pittsburg, Pa.
Nov. 20, '88.	Palmer, W. P.,	37 Beach St., Allegheny, Pa.
Sept. 18, '88.	Park, J. G.,	Room 90, Westinghouse Bldg., Pittsburg, Pa.
Jan. 6, '80.	Parkin, Chas.,	Parnassus, Pa.
Apr. 15, '84.	Parkin, Walter F.,	136 First Ave., Pittsburg, Pa.
Feb. 22, '81.	Patterson, Peter,	National Tube Works, McKeesport, Pa.
Nov. 15, '81.	Paul, J. W.,	Verona Tool W'ks, Seventh Ave. and Liberty St., Pittsburg, Pa.
Apr. 15, '84.	Paulson, Frank G.,	Hatter, Wood St., Pittsburg, Pa.

Date of Membership.		
Mar. 15, '87.	Pease, Chas. T.,	Westinghouse Electric Co., Pittsburg, Pa.
Sept. 18, '83.	Peebles, Andrew,	Architect, Schmidt & Friday Building, Pittsburg, Pa.
Jan. 20, '80.	Phillips, F. C.,	Prof. of Chemistry, 59 Sherman Ave., Allegheny, Pa.
Jan. 16, '83.	Phipps, Henry, Jr.,	Carnegie, Phipps & Co., Ltd., Pittsburg, Pa.
Dec. 20, '81.	Porter, John C.,	Spang Steel and Iron Co., Pittsburg, Pa.
May 17, '87.	Porter, John E.,	Iron Broker, Penn and Second Sts., Pittsburg, Pa.
Jan. 16, '83.	Prentice, W. J.,	Cement, Lime & Terra Cotta, 1009 Liberty St., Pittsburg, Pa.
Dec. 18, '88.	Purves, Jas.,	Munhall, Pa.
Jan. 6, '80.	Quincy, W. C.,	Mon. Con. R. R., 3d Ave. and Try St., Pittsburg, Pa.
Mar. 15, '81.	Ramsey, Jos., Jr.,	Asst. V.-Pres. C. C. C. I. & St. L. Ry., Cincinnati, O.
Dec. 16, '90.	Randolf, Alfred,	53 Carson St., Pittsburg, Pa.
Jan. 20, '80.	Reed, Jas.,	Supt. W. Penn. Div. P. R.R. Allegheny, Pa.
Dec. 17, '89.	Reed, J. R.,	150 Fayette St., Allegheny, Pa.
Jan. 20, '80.	Rees, Thos. M.,	Machinist, J. Rees & Sons, Pittsburg, Pa.
June 19, '88.	Reinmann, A. L.,	Westinghouse Electric Co., Pittsburg, Pa.
May 15, '83.	Reno, Geo. E.,	90 4th Ave., Pittsburg, Pa.
Nov. 17, '91.	Rhea, Frank,	Western University, Allegheny, Pa.
Jan. 9, '80.	Rhodes, Joshua,	Penna. Tube Works, Pittsburg, Pa.
Jan. 6, '80.	Ricketson, John H.,	Founder, 6 Wood St., Pittsburg, Pa.

Date of Membership.		
Apr. 19, '87.	Rider, Percy S.,	6 Ninth St., Pittsburg, Pa.
Apr. 15, '90.	Ritchie, Jas.,	Pittsburg, Pa.
Jan. 17, '88.	Robbins, F. L.,	Penn Bldg., Pittsburg, Pa.
Jan. 7, '80.	Roberts, Thos. P.,	C. Engineer, Craig St. north of Center Ave., Pittsburg, Pa.
Jan. 7, '80.	Rodd, Thos.,	Penna. Co., Pittsburg, Pa.
Nov. 19, '89.	Ruhe, C. H. Williams,	102 Bluff St., Pittsburg, Pa.
Jan. 17, '88.	Ruud, Edwin,	Fuel, Gas & Mfg. Co., Pittsburg, Pa.
May 19, '91.	Sawyer, Thos. I. J.,	1 Garrison St., Allegheny, Pa.
Apr. 15, '84.	Scaife, O. P.,	Wm. B. Scaife & Sons, Structural Iron Works, 119 First Ave., Pittsburg, Pa.
Mar. 20, 83.	Scaife, W. Lucien,	Scaife Foundry & Machine Co., Twenty-Eighth and Smallman Sts., Pittsburg, Pa.
Sept. 20, '87.	Scaife, W. Marcelin,	336 Ridge Ave., Allegheny, Pa.
Feb. 21, '82.	Schellenberg, F. Z.,	Sewickly, Pa.
Jan. 6, '80.	Schinneller, Jacob,	M.E., Room 31, McClintock Block, Pittsburg, Pa.
Feb. 17, '85.	Schmid, Alb.,	Westinghouse Electric Co., Pittsburg, Pa.
May 15, '83.	Schook, Levi,	First Ave and Ferry Sts., Pittsburg, Pa.
Jan. 6, '80.	Schultz, A. L.,	Hiland Ave., E. E., Pittsburg, Pa.
Sept. 19, '82.	Schultz, C. J.,	Iron City Bridge Works, Pittsburg, Pa.
Nov. 15, '81.	Schwartz, F. H.,	5000 Liberty St., Pittsburg, Pa.
Mar. 18, '84.	Schwartz, J. E.,	61 Fourth Ave., Pittsburg, Pa.

Date of Membership.		
Apr. 15, '90.	Scott, Chas. F.,	Westinghouse Electric Co., Pittsburg, Pa.
Feb. 17, '91.	Scott, E. K.,	Keystone Bridge Co., Pittsburg, Pa.
Sept. 16, '90.	Scott, J. B.,	122 2d Ave., Pittsburg, Pa.
Jan. 16, '83.	Seaver, J. W.,	79 Fremont St., Allegheny, Pa.
Jan. 22, '89.	Shaw, A. G.,	County Eng. Office, Pittsburg, Pa.
Jan. 22, '89.	Shaw, W. W.,	County Engineer's Office, Pittsburg, Pa.
Sept. 19, '82.	Sherzer, W.,	C. E., 209 Home Insurance Building, Chicago, Ill.
Nov. 24, '85.	Shultz, O. G.,	McKee's Rocks P. O., Pa.
Dec. 29, '87,	Simpson, Jas. H.,	Carnegie, Phipps & Co., Ltd. Pittsburg, Pa.
Sept. 21, '80.	Singer, Harton G.,	83 Water St., Pittsburg, Pa.
May 20, '90.	Singer, R. R.,	111 4th Ave., Pittsburg, Pa.
Sept. 21, '80.	Singer, W. H.,	Singer, Nimick & Co.. Pittsburg, Pa.
Jan. 21, '90.	Smith, F. S.,	Westinghouse Electric Co., Pittsburg, Pa.
Feb. 17, '80.	Snyder, Antes,	Eng. Right of Way, P.R.R., Blairsville, Pa.
Apr. 15, '84.	Snyder, W. P.,	German Nat'l Bk. Bldg., Pittsburg, Pa.
Jan. 18, '88.	Speer, B.,	Prof. of Physics, Pitts. High School, Pittsburg, Pa.
Feb. 17, '80.	Sprague, H. N.,	Porter & Co., Loco. Works, Pittsburg, Pa.
May 19, '81.	Stafford, C. E.,	Shoenberger & Co., Pittsburg, Pa.
May 19, '83.	Stevenson, David A.,	Civil Engineer, Room 6, Union Station, Pittsburg, Pa.
Jan. 19, '86.	Stevenson, W. S.,	Fairmount, W. Va.

Date of Membership.		
Nov. 21, '82.	Stewart, Geo. R.,	Gas Engineer, Penn Bldg., Pittsburg, Pa.
Oct. 19, '86.	Stewart, J. H.,	Care F. F. Vandevort & Co., Lewis Blk., Pittsburg, Pa.
Jan. 6, '80.	Stillburg, J. H.,	Architect, 20 Fifth Ave., Pittsburg, Pa.
Jan. 21, '90.	Stillwell, L. B.,	Westinghouse Electric Co., Pittsburg, Pa.
Oct. 21, '90.	Stowe, H. C.,	Room 801 Penn Bldg., Pittsburg, Pa.
Jan. 6, '80.	Strobel, C. L.,	M. E., 205 LaSalle St., Chicago, Ill.
Feb. 17, '91.	Stupakoff, S. H.,	Union Switch and Signal Co., Swissvale, Pa.
Nov. 17, '91.	Sugden, C. H.,	Carnegie, Phipps & Co., 221 40th St., Pittsburg, Pa.
Feb. 20, '83.	Swan, Robert,	Civil Eng., Allegheny Ave., Allegheny, Pa.
Apr. 19, '87.	Swensson, Emil,	Keystone Bridge Works, Pittsburg, Pa.
Oct. 20, '91.	Tallman, F. G.,	712 Hamilton Bldg., Pittsburg, Pa.
Apr. 20, '80.	Taylor, E. B.,	Genl. Supt. Penna Co., Pittsburg, Pa.
Dec. 16, '90.	Temple, W. C.,	408 Lewis Block, Pittsburg, Pa.
May 18, '86.	Tener, Geo. E.,	Edith Furnace Co., Allegheny, Pa.
Dec. 21, '81.	Thaw, Wm., Jr.,	Hecla Coke Co., 21 Lincoln Ave., Allegheny, Pa.
Apr. 19, '89.	Thorsell, J. A.,	119 First Ave., Pittsburg, Pa.
Apr. 9, '91.	Tibbitt, C. H.,	68 Sixth Ave., Pittsburg, Pa.
Mar. 18, '91.	Tone, S. L.,	4624 Filmore St., Pittsburg, Pa.
Dec. 16, '90.	Tonnelé, Theo.,	McKeesport, Pa.
Jan. 6, '80.	Trimble, Robt.,	Penna. Co., Pittsburg, Pa.

Date of Membership.		
Feb. 22, '81.	Utley, Edwd. H.,	A. V. R. R., Pittsburg, Pa.
Feb. 16, '92.	Vandevort, Theo.,	Blairsville, Pa.
May 19, '85.	Verner, M. S.,	Supt. Citizens' Traction Co., 939 Penn Ave., Pittsburg, Pa.
Dec. 20, '87.	Verner, Henry W.,	8 Wood St., Pittsburg, Pa.
Apr. 18, '82.	Wainwright, J.,	C. E., 111 Fourth Ave., Pittsburg, Pa.
Apr. 19, '87.	Wainwright, J. R.,	P. O. Box 264, Pittsburg, Pa.
Jan. 6, '80.	Walker, J. W.,	Forty-seventh St. and A. V. R. R., Pittsburg, Pa.
Dec. 15, '91.	Walker, Robt. L.,	Room 317, Lewis Block, Pittsburg, Pa.
Jan. 16, '83.	Warden, C. F.,	Greensburg, Pa.
Jan. 6, '80.	Weeks, Jos. D.,	Editor Amer. Manufacturer, Box 1547, Pittsburg, Pa.
Apr. 19, '87.	Weiskopf, Saml. C.,	Box 732, Pittsburg, Pa.
Feb. 21, '82.	Westerman, Thos.,	Verona Tool Works, Verona, Pa.
May 15, '83.	White, T. S.,	Penna. Bridge Works, Beaver Falls, Pa.
May 18, '80.	Wickersham, S. M.,	C. Eng., Home St., Allegheny, Pa.
Oct. 19, '80.	Wickersham, Thos.,	Mill Mgr., Park Bros. & Co., Pittsburg, Pa.
Oct. 21, '90.	Wieland, C. F.,	Care Riter & Conley, Allegheny, Pa.
May 18, '86.	Wierman, Victor,	Eng. Pgh. Div. P. R. R., Pittsburg, Pa.
Jan. 21, '90.	Wigham, Wm.,	Camden, Pa.
Feb. 17, '80.	Wightman, D. A.,	Supt. Pittsburg Loco. Works, Box 76, Allegheny, Pa.
Jan. 6, '80.	Wilcox, John F.,	J. P. Witherow, Lewis Block, Pittsburg, Pa.
May 15, '87.	Wilkins, W. G.,	C. E., 244 Western Ave., Allegheny, Pa.

Date of Membership.		
Jan. 19, '86.	Wilson, Howard M.,	Founder, 4610 Filmore St., Pittsburg, Pa.
Jan. 18, '88.	Wilson, F. T.,	Jersey Shore, Lycoming Co., Pa.
Jan. 18, '88.	Wilson, W. R.,	319 Lewis Block, Pittsburg, Pa.
Feb. 20, '88.	Winn, Isaac,	National Rolling Mill, McKeesport, Pa.
Jan. 6, '80.	Witherow, J. P.,	Eng. and Contractor, Lewis Block, Pittsburg, Pa.
Nov. 19, '89.	Wolffe, J. J. E.,	Keystone Bridge Co., Pittsburg, Pa.
Jan. 15, '84.	Wood, B. L., Jr.,	Mon. Dredging Co., 43 Sixth Ave., Pittsburg, Pa.
Sept. 21, '80.	Wood, R. G.,	Iron Mills, McKeesport, Pa.
Jan. 18, '88.	Wood, Jos.,	Genl. Supt. Transportation Pa. Lines, Pittsburg, Pa.
Jan. 18, '88.	Woods, Leonard G.,	East End Hotel, Pittsburg, Pa.
Jan. 6, '80.	Zimmerman, W. F.,	U. S. Electric Co., Newark, N. J.

CORRESPONDENTS.

Society of Arts,	Boston, Mass.
Massachusetts Institute of Technology, Department of Civil Engineering,	Boston, Mass.
Boston Society of Engineers,	City Hall, Boston, Mass.
Brinsmade, D. S., Sec. Conn. Assoc. of Civil Engineers and Surveyors,	Birmingham, Conn.
State Association of Engineers,	Norwich, Conn.
American Scientific Society,	219 River St., Troy, N. Y.
Sibley College,	Cornell University, Ithaca, N. Y.
American Society of Civil Engineers,	127 East 23d St., New York.
American Society of Mechanical Engineers,	60 Madison Ave., New York.
American Institute of Mining Engineers,	Lock Box 223, New York.
Journal of Association of Engineering Societies,	73 Broadway, New York.
Railroad and Engineering Journal,	46 Broadway, New York.
Tichnischer Verein,	210 E. Fifth St., New York.
Engineering News,	Tribune Building, New York.
University of Illinois,	Champaign, Illinois.
Library of Second Geological Survey of Pennsylvania,	P. O. Bldg., 4th floor, Room 18, Philadelphia, Pa.
Franklin Institute,	18 S. Seventh St., Philadelphia, Pa.
Engineers' Club of Philadelphia,	1122 Girard St., Philadelphia, Pa.
Tichnischer Verein,	106 Randolph St., Chicago, Ill.
Railway Review,	Chicago, Ill.

American Engineer, Chicago, Ill.
Western Society of Engineers, 78 LaSalle St., Chicago, Ill.
Civil Engineers' Club of Cleveland, Cleveland, O.
Indiana Society of Civil Engineers and Surveyors,
Remington, Ind.
Engineers' Club of St. Louis, St. Louis, Mo.
Engineers' Club, Kansas City, Mo.
E. S. Cunningham, Columbia, Boone Co., Mo.
B. Thompson, Box 430, Chattanooga, Tenn.
J. M. Whitman,
Arkansas Industrial University, Fayetteville, Ark.
The Practical Mechanic, Worcester, Mass.
Liverpool Engineering Society,
Colquit St., Liverpool, England.
Iron and Steel Institute, Lombard St., London, E. C.
The Technic, Ann Arbor, Mich.
Stevens Institute of Technology, Hoboken, N. J.
Engineering and Mining Journal, 27 Park Place, New York.
Journal of Society of Arts, John St., Adelphi, London, W. C.
Institution of Civil Engineering,
25 Great George St., Westminster, London, S. W.
Society of Civil Engineers,
Westminster Chambers, London, S. W.
London Patent Office, London, England.
Swedish Society of Civil Engineers, Stockholm, Sweden.
Associadad dos Engenheiros Civis Portuguezos,
Lisboa, Portuguezos.
Sociadad Cientifica Argentina, Buenos Aires, S. A.
Club de Engenharia, Rio de Janeiro, Brazil, S. A.
Henry A. Gordon, Inspecting Engineer,
Wellington, New Zealand.
Annales des Mines, Paris, France.
E. Ingeniero Civil,
424 Corrientes, Buenos Aires, Argentine Republic, S. A.
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Nashville, Tenn.

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5 Beekman St., New York.
Smithsonian Institution, Washington, D. C.
American Journal of Railway Appliances,
113 Liberty St., New York.
The Technical Society of the Pacific Coast,
408 California St., San Francisco, Cal.
California State Mining Bureau.
Svenska Teknologforeningen, Stockholm, Sweden.
Fairchild, D. G., Geneva, N. Y.
Ohio Society of Surveyors and Civil Engineers, Massillon, O.
Johnson, J. B., Index Dept. Jour. Ass. Eng. Society,
Washington University, St. Louis, Mo.